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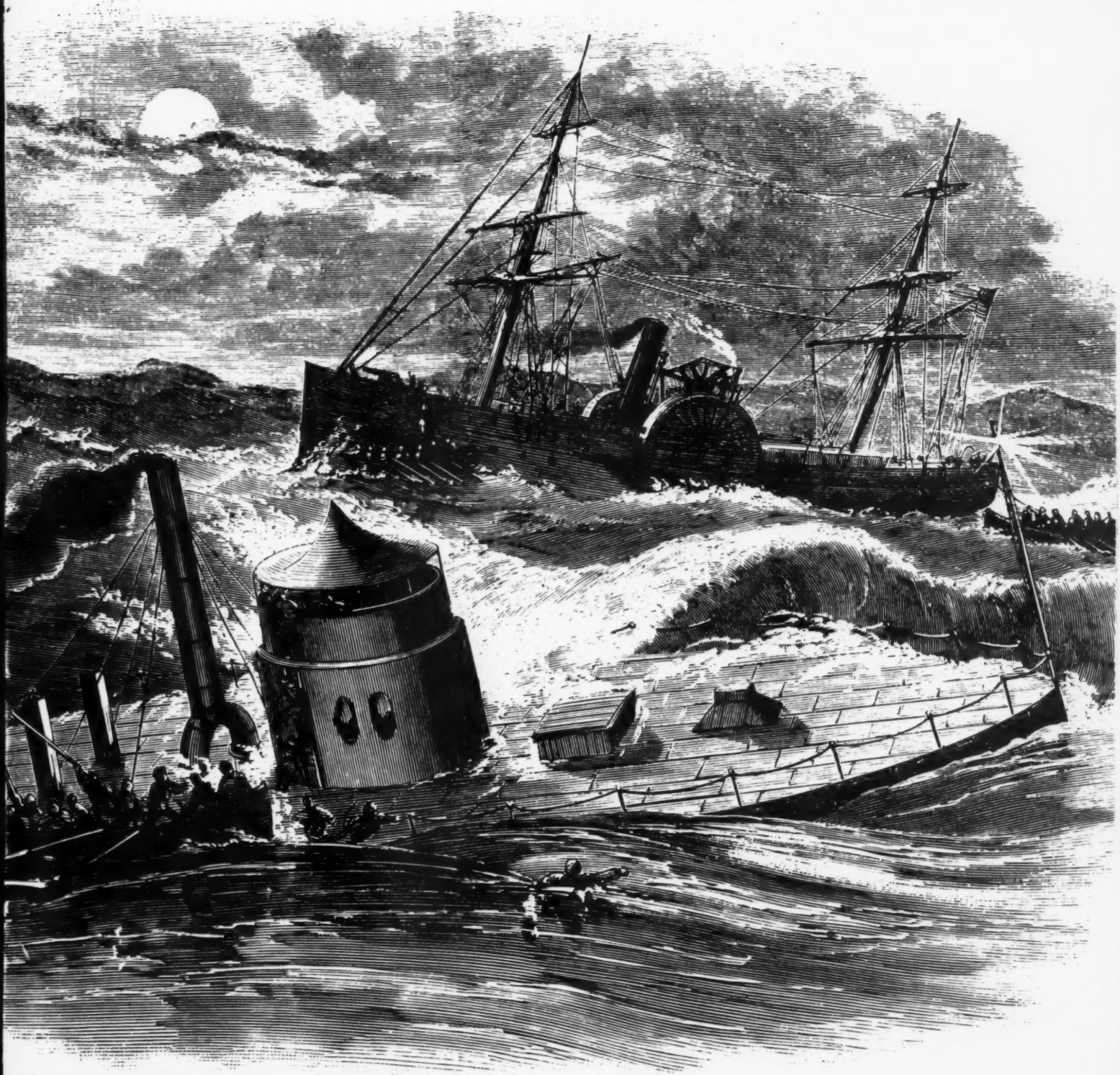

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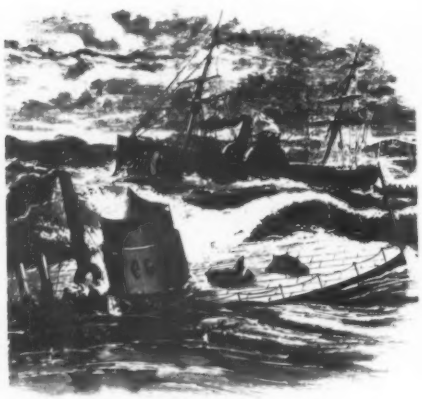

COVER: Engraving from "Harper's Weekly" of January 24, 1863, captured--with considerable artistic license--the high drama of the famed USS Monitor's last moments. (See story, page 12).

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Toward a New Law of the Sea

Howard W. Pollock
Deputy Administrator

The Law of the Sea negotiations that began in Caracas in the summer of 1974, and are continuing in Geneva, deal with problems of fundamental importance to NOAA and to the United States. Many of these highly controversial problems will be difficult to resolve. It is, however, very important that agreement be reached.

Lest anyone be discouraged by the apparent slowness of the conferees to agree, it should be noted that this is the largest accumulation of nations ever to come together in the history of the world—larger even than the present-day membership of the United Nations. Represented are coastal and landlocked nations, highly developed and lesser developed nations, nations with every conceivable mixture of interests and experience in ocean affairs. And they are trying to resolve problems concerned with the management of nearly three-fourths of the world's surface—that part covered by the oceans and the underlying continental margins and deep seabed.

Within the United States, NOAA and the Department of Commerce have a broader interest in the substantive issues of the conference than any other single agency. It is for this reason that the NOAA team that worked on preparations for the conference was given the responsibility for coordinating the Departmental position in deliberations within the United States delegation and staff of experts.

NOAA's interests cover the marine environment, the continental shelf, the deep seabed, marine mining and minerals, navigation, fisheries, and research—to name only the most important.

In the briefest possible terms, the United States position on areas of key importance to NOAA is:

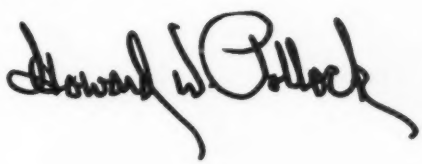
—to guarantee to U.S. firms, under reasonable conditions, access to the mineral resources, especially manganese nodules, of the deep seabed;

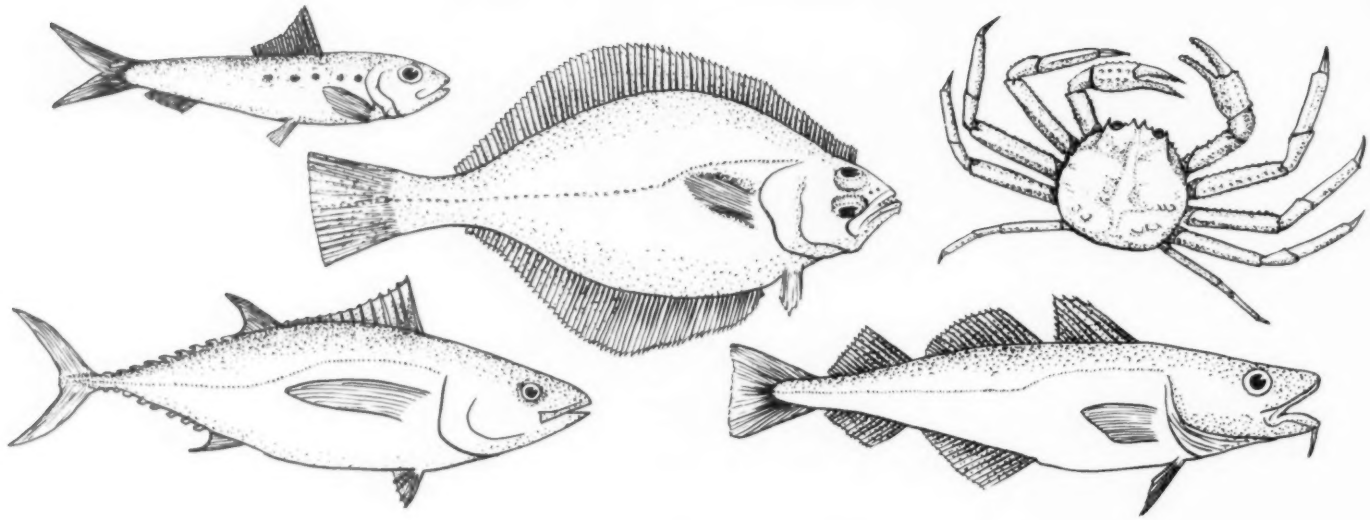
—to protect the marine environment;

—to maximize freedom of research beyond the territorial seas;

—to give coastal states regulatory authority over coastal and anadromous fish, with concomitant duties of conservation and full utilization, and to provide international or regional regulation of tuna.

The issues affect units and programs throughout the NOAA organization. As the meetings and committee sessions progress, and as the United States presents its position, the NOAA family can know that, in a very real sense, their activities are closely identified with the national interest and with the success of our delegation. Their ideas and support have been of great assistance in drafting the American viewpoint.





A noted expert looks at the factors underlying food from the sea

FISH FOR

BY DAYTON L. ALVERSON*

The potential of the oceans to provide food for mankind has been the subject of considerable debate, particularly during the last two decades. Now it has taken on urgent, practical meaning. Throughout the world there is growing concern about the adequacy of food supplies of all kinds. Drought in Africa, the limits reached by the "Green Revolution," and uncertainty about possible changes in weather patterns have all fueled this concern. The World Food Conference held in Rome last year under the auspices of the United Nations was a manifestation of the global interest in this problem.

Using the best information now available to scientists for determining the potential production of the oceans, and assuming a stable world order that protects species from overfishing and allows full use of the biological surplus produced by nature, it would appear that:

(1) for conventional (already popular) species, there is a biological basis to increase production from two to four times the present harvest; and

(2) for unconventional species (those that are perfectly edible but not yet widely known to mankind), the oceans could yield at least ten times the present harvest. These values, however, must be tempered by a realistic appraisal of socio-economic and institutional problems which influence production capabilities.

The question is: Just what options are available to increase fish production from the 70 percent of the world's surface that is covered by the ocean? The answer depends upon three major factors. The first is the capacity of the oceans to produce food; that is, what possibilities and what limitations has nature provided? Once these are understood, we can examine technical-economic and social-political factors which may influence future catch trends.

Estimates of the ocean's potential to produce food have been made using several techniques. The earliest forecasts were founded on results of biological surveys and historical catch trends. These estimates were frequently confined to exploitation of traditional species such as tunas, flounders, cods, shrimps, and herrings. In more recent years, a number of scientists have made estimates of potential yield by examining the amount of phytoplankton produced in the oceans each year and the subsequent flow of the material produced through the food chain.

Estimates derived from biological survey data and catch trends have, for the most part, been rather conservative, ranging from 55-100 million metric tons. The present world catch of marine fish and shellfish passed the lower forecasted value several years ago, and we are currently harvesting about 60 million metric tons per year.

More interesting forecasts have been derived in recent years through evaluating primary production; that is, the amount of material that is produced each year by photosynthetic processes. Phytoplankton, the minuscule plant life that forms the lowest level of the oceanic food chain, stores energy by carbon fixation—that is, naturally occurring inorganic carbon is chemically bound through photosynthesis to create carbohydrates. The phytoplankton that store carbohydrates form the food base of all higher levels in the food chain. Considering the efficiency by which this material is passed up through the food chain, scientists can estimate the amount of biological material existing at a given level of the chain.

Authors who have dabbled in these mental gymnastics have come up with estimates of potential total world fish catches ranging from 100 million to 2,000 million metric tons per year.

The wide range of these forecasts may cast doubt on the validity of the technique. Several factors account for the disparity; one is concerned with the differences in estimates of total primary production. In recent years, however, calculations of the amount of organic carbon fixed annually through photosynthesis have narrowed considerably. The Russian scientist, Peter Moiseev, in 1971 estimated the range as from 19 billion to 23 billion tons per year, a range that is now commonly accepted. The variation in estimates of the amount of fish that might be produced from "fixed carbon" results largely from different views about which trophic level—that is, which level in the food chain—the harvest might be taken, and different views about the efficiency of material transfer from lower to higher trophic levels.

One highly theoretical approach was taken by Dr. Wolf Vishniac of the University of Rochester, who examined the problem, starting with radiant energy of the sun in watts. From this, he calculated the earth's calorie intercept, and then step-by-step he led us to an estimate of possible total world fish production, which he calculated at 240 million metric tons—a value which fits nicely into the range forecasted by other scientists.

A number of scientists have reservations about estimates based on carbon production, stating they provide little in the way of useful information about species types and about areas of the world where fisheries might be expanded—in other words, that

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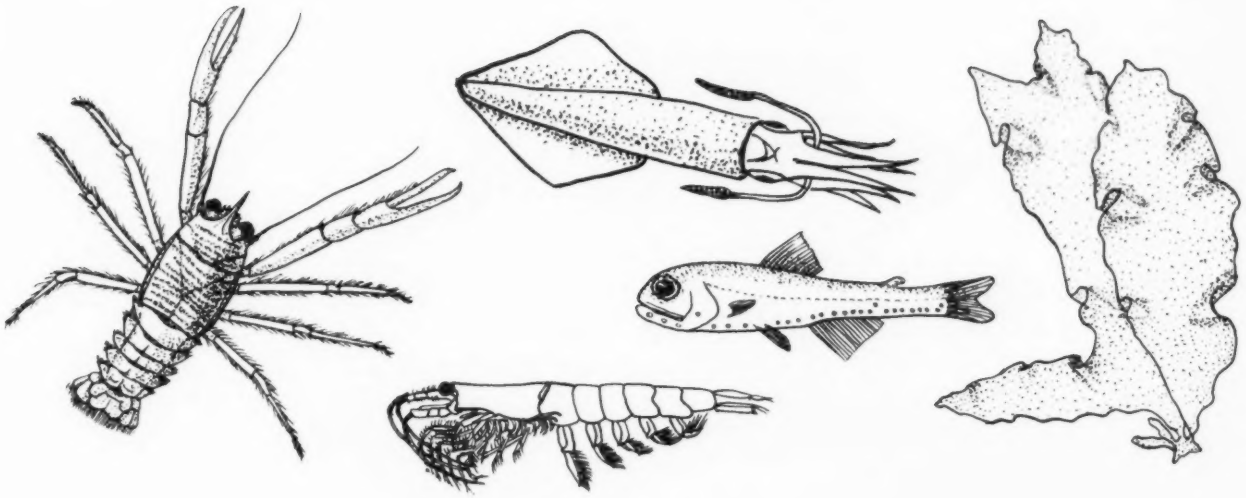


A HUNGRY WORLD

such estimates are largely academic. On the specific charges they may be right; but on the general charge, they are dead wrong. All in all, studies of food chain dynamics have added more to our knowledge of biological production in the seas than other forecasting techniques.

Although major portions of the world's oceans are often called "biological deserts," the total quantity of biological material produced is tremendous. The amount of first-stage carnivores (zooplankton) has been estimated at 1.9 billion to 2.3 billion metric tons per year—about one-hundredth of the estimated annual production for phytoplankton, and ten times the estimated potential biological harvest for conventional fish and shellfish species. Although these values are helpful in understanding the general productivity of the oceans and the quantity of biological material produced at various levels of the food chain, they must be put into proper perspective when evaluating potential increases in food from the sea.

The most recent estimates associated with the biological basis for developing conventional marine fisheries range from 100 million to 250 million metric tons—two to four times the existing world catch. The next question is: Where does it exist and in what form?

Opportunities for further development of traditional fisheries appear best in the Southern Hemisphere: For demersal stocks (bottom fish such as flounder), increases can be expected off the east and west coasts of South America, Australia, New Zealand, and Southeast Asia. Further growth of demersal fisheries should also occur off the west coast of Africa, and some expansion of reef fishes in the tropic and subtropic areas is feasible. Pelagic (midwater) stocks such as small tunas, jacks, anchovies, and sauries constitute the largest underexploited resources available for increased production of traditional forms. Potential growth for fisheries based on these species is best in the coastal regions of the Southern Hemisphere and in the Indian Ocean.

If in addition we consider the unconventional forms, the biological basis for expansion is relatively enormous. The opportunities appear best for krill, red crab, squid, lanternfish, and seaweed (yes, seaweed!).

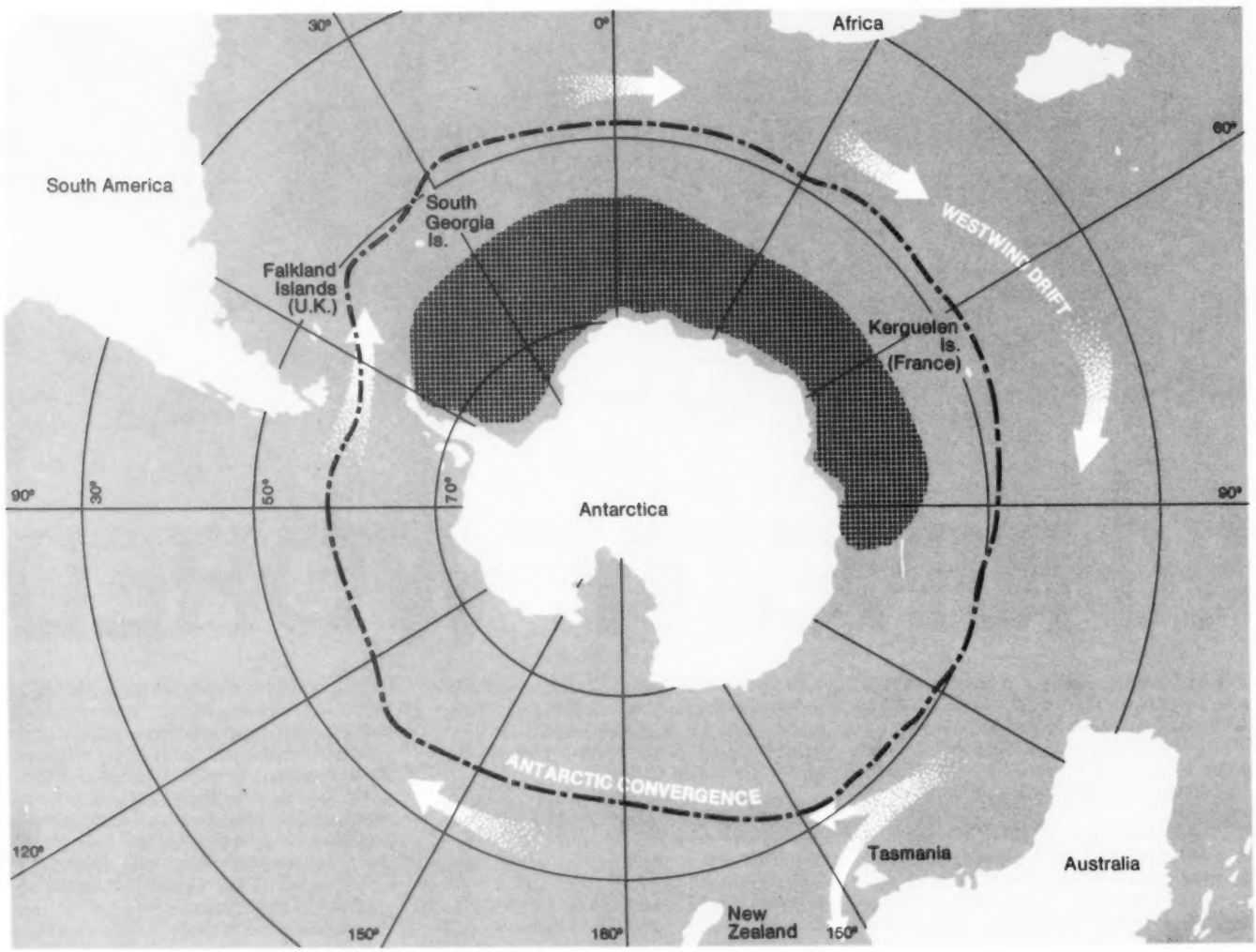
The most frequently mentioned unconventional form is the Antarctic krill (*Euphausia superba*). Over the past several years, Soviet and Japanese scientists have investigated the distribution, abundance, and use of Antarctic krill, which reaches a maximum size of about three inches (7 cm) and has a circumpolar distribution between the Antarctic convergence (50-60°s) and the continent of Antarctica. Krill are generally found in the upper layers to depths of 250 meters and swarm at or near the surface. In his 1971 paper, Moiseev reported that the swarms may attain a density of 22 to 35 pounds (10-16 kg) per cubic meter. Investigations by Soviet and Japanese scientists have generally been concentrated within the arc intercepting Antarctica, from 60°W long. to 90°E long. Soviet scientists found highest concentrations in and around the Scotia Sea, while Japanese investigations have had somewhat better luck in water farther east.

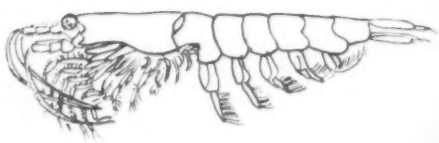
In 1973, Soviet experts estimated that the standing stock of Antarctic krill ranges from 800 million to 5,000 million tons and forecast an annual yield of at least 100 million tons. This yield forecast seems small compared to the standing stock estimates, but it does closely fall within the range of forecasts made by John Gulland in 1971 (200 million tons) and the Japanese scientist Omura in 1973 (100-200 million tons per year). These figures greatly exceed the present total annual world catch of all aquatic resources.

Another crustacean that reaches moderate size is the red crab (*Pleuroncodes planipes*), one of the principal food items of tuna in the Eastern Tropical Pacific. It is similar to, but slightly smaller than the "langostino" that is heavily harvested off Chile for human consumption, and not to be confused with the much larger red crab (*Geryon quiquedens*), an underutilized species beginning to be harvested in the western Atlantic. The Pacific red crab frequently occurs in large swarms near the surface. Alan Longhurst suggested in 1968 that the resource off the Pacific coast of North America should be used as food, and estimated a potential annual production of 30-300 thousand tons of these crustaceans off lower California and Mexico; more recent studies suggest an even larger potential yield.

A third possibility is squid, but the scientific basis for forecasting latent squid resources is of an even more speculative nature. Gilbert Voss suggested in 1973 that the worldwide cephalopod catch from continental shelf waters alone could be increased from the present level of one million metric tons to about eight million metric tons per year. Oceanic squid yield, estimated mainly on the basis of the predation by sperm whales, is suggested to be more than 50 times that amount. Moiseev lent some supporting evidence to squid abundance, noting in 1971 that their shells are common in marine sediments and that several species are widespread in the oceanic and neritic (inshore; areas overlying the continental shelf and slope) zones of tropical, subtropical, and boreal regions of the world.

Marine biologists have also speculated on the potential for developing fisheries for lanternfish. Gulland estimated in 1971 that lanternfish could provide a harvest up to 100 million metric tons per year. The Myctophid family, of which lanternfish are a part, is





An artist's drawing of a single krill, which can be fished in the Antarctic using midwater and surface trawls and purse seines. Recent catches have been promising, especially with midwater trawls. The photo on the right shows a deck load of swimming crabs caught during trawl surveys by the NOAA ship David Starr Jordan off Baja California.

widespread throughout the world's ocean, and recent investigations of midwater fishes by Gerhard Krefft have extended our knowledge of their distribution. Although our knowledge of small, ubiquitous, pelagic fishes is still sparse, lanternfish along with other small oceanic species may produce a sustainable yield that exceeds 100-200 million metric tons per year.

The world harvest of seaweeds probably now exceeds one million metric tons per year. The potential for increase is not well known. While no quantitative estimates have been attempted, John Gulland noted that the majority of the existing production comes from a small area in the northwest Pacific. Unless natural production in other parts of the world is very much lower, the present world harvest could certainly be increased several-fold.

In terms of biological potential, then, the conclusion is simple. The oceans do produce enormous quantities of biological material. Even in terms of conventional forms, the surplus biological production may be two to four times that which is now harvested. If one turns to unconventional forms, limited to species for which we have some basis for quantifying their potential, the biological basis for expansion is about ten times greater than current world marine fish harvest. Finally, the foregoing discussion of biological bases for expansion of fisheries was confined to wild stocks, and we must recognize opportunities exist to improve ocean production through ecological modifications, transplantations, and aquaculture.

Since World War II, there has been a rapid advancement in fishing technology, particularly as it concerns vessels, electronics, and materials used in fishing activities. Most of the fishing fleets that were destroyed during the War were rapidly replaced with modern vessels. Improvements in radar, sonar, radio navigational systems, etc., greatly enhanced the development of offshore fishing. Electronic advances were augmented by the introduction of synthetic fibers and the use of hydraulic power to operate a variety of deck machinery. These changes led to increased safety at sea, precision navigation, improved nets, reduced manual labor, and improved fish detection.

By the early 1970's, fishing had become a global activity. Japanese and Soviet vessels were investigating the Antarctic for the abundant krill, tuna fishing was being undertaken in the north and south Atlantic and Pacific Oceans and throughout most of the Indian Ocean. European fisheries had expanded north to the Arctic icepacks, and most of the productive continental shelf areas of the world were subject to intense fishing. Fishing and support vessels currently used are capable of operating in all of the world's ice-free oceans.

Existing fish detection and extraction systems are adequate for expanded operations and for harvesting any unexploited concentrations of demersal or pelagic fishes. Technology does provide the basis for increasing the harvest of conventional forms. However, the capacity of existing technology to accomplish this is limited by the fact that most large demersal and pelagic fish stocks are already highly exploited. Furthermore, although many stocks collectively may comprise large resources, they are sparsely distributed per unit volume of water and their effective use necessitates development of more efficient extraction systems.

Opportunities for increased fish and shellfish production, 1985 and 2000.

Resource Category	Potential Increases (kilotons)	
	1985	2000
Conventional	8,000	14,000
Unconventional	5,000	35,000
Waste elimination (equivalents)	2,000	15,000
TOTAL	15,000	64,000

Moiseev has noted that any further substantial increase in total catch will depend on man's ability to concentrate fish artificially, to improve the efficiency of fishing gear, and to learn to control the behavior of fish. Despite dramatic changes in the size and design of fishing vessels, propulsion engines, electronics, and materials, the fact remains that there have been no major alterations during this century in the basic techniques used to extract wild stocks from the ocean. Fishing gear used may have increased in size and become mechanized, but we still harvest most fish and shellfish from the sea with nets and hooks-and-lines.

The variety of exotic techniques that have been tried in the last two decades (electrofishing, lights, air bubble curtains, etc.), have not contributed substantially to increased fish production. Major increases in harvesting conventional species will require a technological breakthrough to allow fishing at low stock densities.

There appears to be a better chance to resolve technological problems inhibiting use of some of the unconventional species being considered. Most of them are found in schools of such density that they can be detected and harvested using traditional fishing techniques, with minor modifications. In addition, progress has been made during the past several years in their processing and marketing.

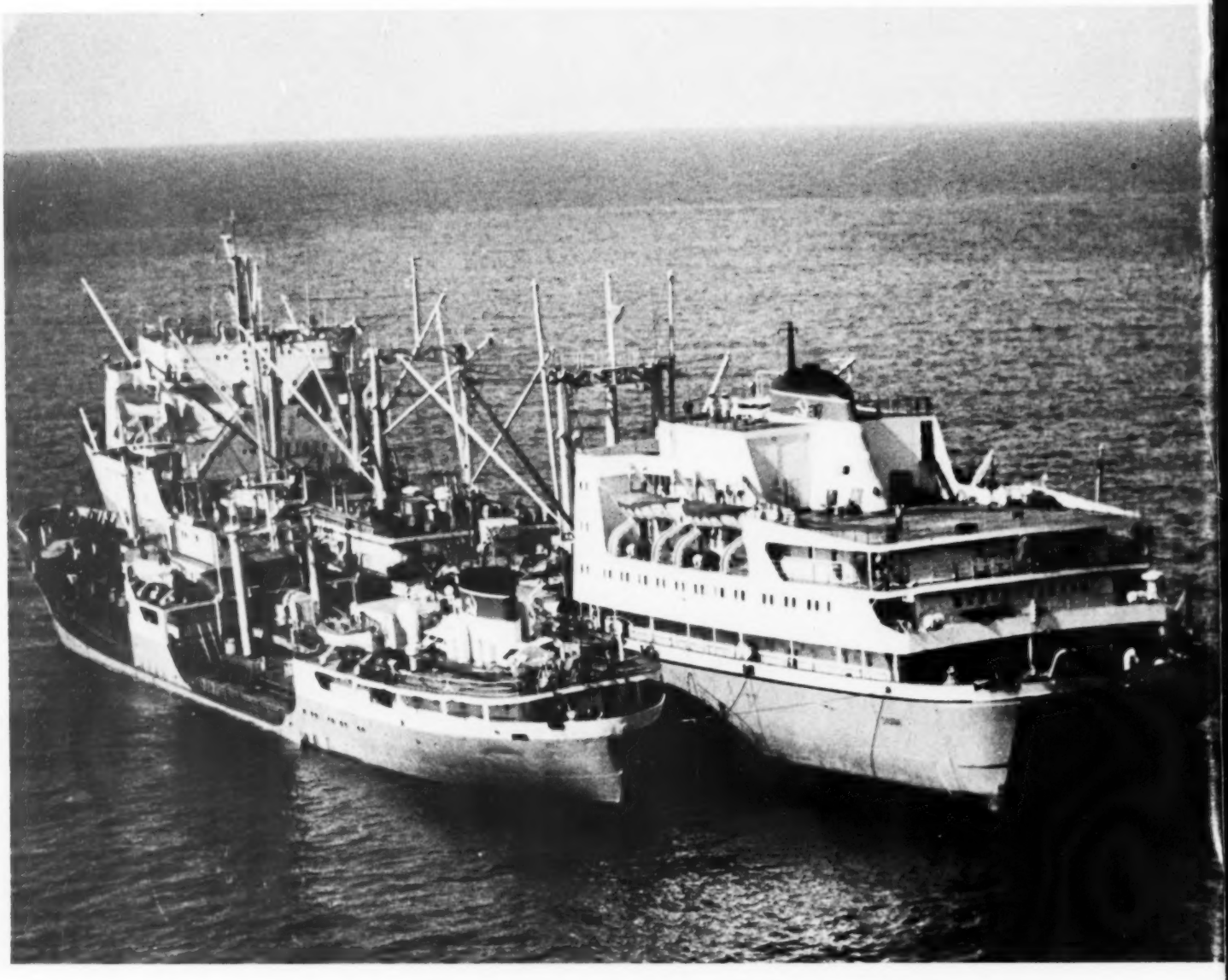
Antarctic krill can be detected by sight at the sea surface or by acoustical methods and can be fished using midwater and surface trawls and purse seines. Recent catches have been promising, particularly with midwater trawls. In early 1974, a 1,500 gross ton Japanese freezer trawler reportedly caught 645 tons of krill in 2½ months of fishing. The catch taken with a midwater trawl, much like those used by small inshore boats, was about 1½ tons per hour trawling. The Soviets have had similar results.

Most experts feel that considerable improvement in catching efficiency can be achieved by using larger and better-designed trawls. But, problems still plague the harvest of krill, especially those of location and detection. Although krill frequently swarm at the surface, recent studies show they may migrate to deeper waters where they are difficult to detect. Development of a special acoustical technique for detection is under consideration. If the fisheries are to prove successful, the variability in occurrence of swarms needs to be defined, and the environmental factors influencing their formation and distribution (temperature and currents) evaluated. The latter could be important in developing methods for locating good fishing areas.

Although major interest in fishing euphausiid (krill) has centered in the Antarctic region, a substantial euphausiid fishery was intiated by Japanese fishermen several decades ago in the western Pacific and annual production of a species known as *Euphausia pacifica* has reached a level of 10,000 tons. The fishery is conducted around Kinkazan on the Pacific coast of Japan and in nearshore waters of Yamaguchi-ken on the Japan Sea. Small-scale krill fisheries have also been established in the northeast Atlantic off Norway, and the product is used as food in aquaculture projects.

Krill are processed in a number of ways. The Japanese have generally frozen krill whole, after boiling, although they also have experimented with drying the product. The Soviets have produced a shrimp paste by squeezing the liquids and exoskeleton out of the tissue under pressure and coagulating the proteins contained in the liquid by heating. The yield of krill paste is between 17 percent and 25 percent, depending on size. The paste is frozen into blocks, transported to the Soviet Union, and sold directly as "Ocean Paste." It is generally mixed with cheese, butter, and other products. The paste contains 13 percent to 20 percent protein and is reportedly high in essential amino acids.

Similar studies have been conducted on the harvesting and processing of red crabs. In trawling for Pacific hake off Baja California, scientists had difficulty in obtaining fish samples without clogging their nets with



The Soviet factory ship, typical of the Pioneer Class (above), is more than 550 feet long and is estimated to be about 14,000 gross tons. The factory ships are equipped with the latest processing facilities. They provide catcher boats, with fuel and water, fishing gear, provisions and technical assistance as well as social and medical facilities. The factory ships serve a flotilla of catcher vessels.

Underutilized species usually gain wide acceptance when properly prepared. A portion of the buffet shown here (right) includes blue mussels steamed in wine and red crab salad, both abundant but not fully utilized. Other species being introduced at various functions include squid, fried white perch and fried shark.

quantities of red crab. Although some hake and other fishes were caught, the most prominent echo-traces were found to result from pelagic crabs. Catch rates ranging from 1½ tons per 13 minutes of trawling to 5 tons per 30 minutes of trawling were reported. The scientists suggested that at least 20 tons per hour could be caught with appropriate midwater trawl gear. There are, however, the usual problems that must be resolved before we can expect their commercial production. The yield using current technology is low—from 8 percent to 10 percent of the body weight. This may be increased, however, by utilizing pressure techniques to recover edible portions.

A variety of existing fishing techniques can be used to harvest squids and lanternfish. Some species of squid can be attracted to light, and an experimental light pump system has been successfully used in Monterey Bay. If the market demand for squid increases, it is quite likely that existing harvesting systems can be utilized in areas where concentrations are known to occur. Commercial exploitation of lanternfishes using trawls has already started off South Africa. The annual catch of this unconventional group has grown to over 20,000 tons.

There are several technological options available to increase food production from the oceans. We can develop the technology for improving extractive capabilities or we can also increase the amount of available protein through more efficient use of what we now catch.

One step towards this goal could be achieved by recovering higher yields of edible fish that are currently harvested. For example, flesh separating machines have recently been introduced that squeeze the flesh from the skin and bones of fish and pass the flesh through perforations on stainless steel plates or drums. The skin and bones do not pass through the perforations, and hence are separated from the edible portions. Experiments on a variety of fish suggest that the technique may increase the usable yield 50 percent. The technique is currently employed on a fairly large scale in Japan and is finding a growing use in other areas of the world. Flesh-separating machines represent a technological advance that increases food supplies by eliminating waste, and that may represent a large step towards total utilization of fisheries products.

Other gains can be achieved through elimination of spoilage, transfer of fish from industrial products to human consumption, and utilization of species that are caught and discarded at sea. Discards currently represent an unreported harvest which in some fisheries is substantial and which could be eaten directly or used in products such as minced fish.

In addition, catches that are used for production of fishmeal can be gradually transferred to human consumption. There is already a noticeable tendency to use less of the preferred food species, such as herring and mackerel, for fishmeal and more for human consumption. Such trends will have both economic and social advantages, particularly as it relates to improving the total quantity of protein available for direct consumption.

To make optimum use of the potential offered by biology and by technology, there must also be a sound social-political basis for expansion. An obvious condition for continued growth and maintenance of the marine fisheries is a satisfactory arrangement for their international control based on adequate research and logical management procedures. World fisheries are currently in a turmoil stemming from overfishing problems and the changing jurisdictional philosophies manifested at the United Nations Law of the Sea Conference. Although the character of the total package that may emerge from the Conference is difficult to predict, one can foresee major changes in leading to coastal state jurisdiction over resources in a zone adjacent to their territorial sea — that is, the 200-mile economic zone.

Achieving national jurisdictional aspirations, however, will not alone solve overfishing problems. A clarification of changing legal concepts as they deal with jurisdiction over resources or sections of the aquatic environment may be required before radical new management principles can surface. Nevertheless, fundamental management problems will remain; and the solution will depend on the power given the management agencies, their depth of understanding of the reaction of resources to natural and human events, and the willingness of governments to assume responsibilities acquired or delegated to them, including the promulgation and enforcement of appropriate regulations.

It is obvious that slicing the ocean into a series of ocean provinces may create new problems. Management can suffer, particularly if adjacent countries assume that they can "go it alone." Evolution of appropriate regional or international institutions will be a requisite to improved management and improved production for the world's ocean. Without control of total fishing effort and its distribution by region, species, and among countries, technological improvements may, in the end, lead to both biological and economic waste.

Sidney Holt of FAO noted in 1974 that fisheries management agencies have historically been concerned with resource depletion and the resolution of conflicts. We have tried to regulate competition between individuals, user groups, gears, fleets, etc., in an attempt to harmonize user interest in the potential resources and future use. This was probably appropriate inasmuch as the fishing industry was the major economic group exploiting the ocean resources. The situation, however, is changing rapidly. Both oil and minerals are being sought on the continental shelf and slope and deep seabed, estuaries are being used for a variety of industrial and recreational purposes, and the aquatic environment serves as a receptacle for disposal of industrial and human waste. It seems apparent that multiple use of the aquatic environment will become of increasing importance. Hence, in the near future, we may be as much concerned with another problem: harmonizing the fisheries use of the ocean and seabed with other uses and resolving competition between them.

There is evidence that the oceans produce an enormous biological surplus upon which mankind can increase the amount of food produced from the world's oceans. There is, however, a great difference between what is produced and what can be realistically harvested. There may indeed be a biological surplus for conventional species of two to four times that which is now harvested, but technical and social-political constraints may limit catches for these species to no more than 100 million metric tons. If we fail to establish effective national and international management institutions, we may never even approach this figure. In addition to the managerial problems, the maintenance and continued growth of fisheries could depend on an adequate resolution of energy problems. Should oil prices outrun the value of raw material, there could be major setbacks in production of food from the ocean.

Despite these difficulties, some modest increases in the catches of conventional species can be expected over the next 3½ decades. With some improvement in managerial policies, we might expect an increased catch of at least eight million tons of conventional species over the next decade. This is based on the premises that the Peruvian anchovy fishery will rebuild to a level of about eight million metric tons; that there will be continued development of underutilized conventional species, particularly in the Southern Hemisphere and in the Indian Ocean; and that fuller use will be made of the complex of species available for harvest. The rate of growth of conventional forms will, however, continue to decline; and perhaps no more than 14 million tons in addition to what is now caught will be produced before the end of this century.

The unconventional species offer the greatest opportunity for expansion. Changing coastal state jurisdiction may well focus increased use on the Antarctic and open ocean areas of the world. If the cost of locating and extracting krill can be resolved, we might expect production of unconventional forms to approach five million tons in 1985 and increase to 35 million tons by the year 2000.

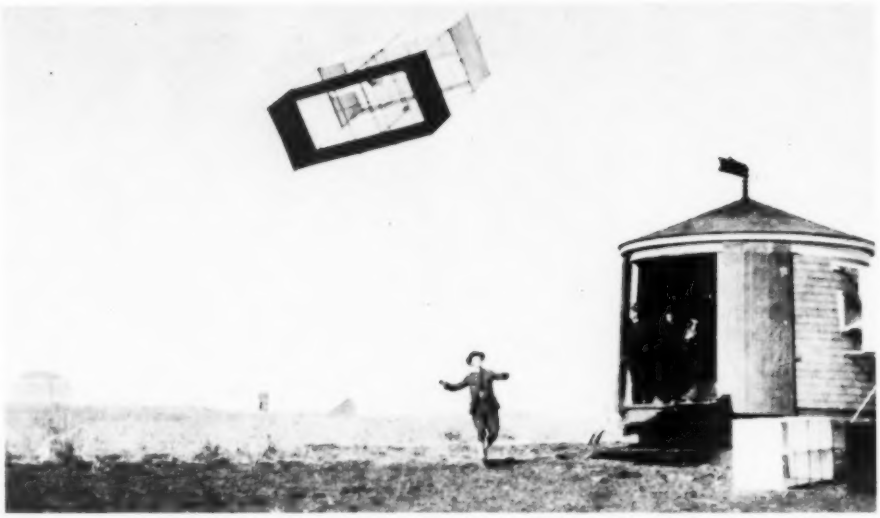
In addition to increased catches which may come from geographical expansion of fisheries operations and exploitation of unconventional species, gains can be achieved through elimination of waste from species now harvested and through transfer of fish used for industrial purposes to products used for direct human consumption. For example, by 1985 the equivalent of two million extra tons of fish could be made available as a result of technological changes and utlization patterns of this type, and this value could be increased to approximately 15 million tons by the year 2000.

The natural order of the oceans—the basic biology—provides humanity with the opportunity for substantial increases in fish and shellfish production. Man's social order, and his technological development, will determine whether the opportunity is seized or lost.

From kites to radiosondes

Weather Sentries in the Sky

BY NANCY PRIDGEON



Ever since stone-age men conjured up supernatural powers to explain a primeval gale, mankind has sought to understand, predict, and even change the weather. But it was not until science and technology came of age that we have begun to have a realistic view of the forces that drive the mighty heat engine we think of as weather. A key element in this improved understanding has been the placement of scientific measuring devices in the ocean of air above our heads.

One such device is the radiosonde. A compact intricacy of sensors, wires, and micropower, it sends back information from where it is now. Flying higher than a kite can reach, and less disruptive of its surroundings than an airplane, the balloon-borne radiosonde—weighing only a few pounds—transmits information to a ground-based receiver as long as it is within range—for a maximum of about 200 miles.

The information the radiosonde transmits on air pressure, temperature, and humidity forms a "profile" of the upper air. Wind speed and direction are also part of the profile when the progress of the sonde—in this case called a "rawinsonde"—is followed by a radio direction finder. Severe storms are greatly influenced by conditions at all levels of the atmosphere. Given enough profiles, the forecaster can compute and predict the probable consequences of the forces at work on any given day.

Penetrating the secrets of the atmosphere has been a truly scientific occupation for little more than 200 years. True, the Chinese flew kites from earliest recorded time, and Ben Franklin managed to escape the electric potential of his kite-flying experiments. But the earliest recorded meteorological use of kites was in 1749 when a chain of kites with thermometers attached to their tails was flown a few hundred feet above the ground. Recovering the thermometers unbroken, Professor Alexander Wilson of the University of Glasgow thus established the kite as a practical method of sounding the atmosphere.

Kites were used over the next 150 years for more atmospheric samplings, but the results were apt to be more random than planned. During the 18th and 19th centuries, free-rising manned balloons came into vogue. The hardy weathermen of those days climbed in beside their instruments to gain what fragmentary knowledge they could. But flights were often perilous and the information limited and irregular.

In the 1890's, Cleveland Abbe—early weather service pioneer and then editor of the *Monthly Weather Review*—thought kites might be the better method. By 1898, the kite had come into its own. Complex box kites, carrying recoverable weather instruments, were flown from 17 U.S. kite stations, attempting daily simultaneous observations.

In 1904, Mount Weather, Virginia (alt. 1764 ft.)—the same Mount Weather that was the site of the tragic December 3, 1974 plane crash—became the center of weather service kite flying activities. A record height of nearly five miles was claimed in 1907. That same year a regularly scheduled kite program was initiated. This early program was limited to seven stations at most, not all of them in use at all times.

Reading the 1910 *Bulletin of the Mount Weather Observatory*, with its astonishing detail for the construction of weather kites, one can glimpse the dedication of the meteorologists in their quest for knowledge. But the kites themselves were sometimes troublesome, usually fragile, and whimsical, after the manner of kites. Sometimes they couldn't be flown at all because of too much or too little wind. Each kite was equipped with a Marvin meteorograph—an instrument to record temperature, pressure, and humidity. Left to fly for four or five hours, the meteorograph was reeled back in along with its host.

The kite program was supplemented by unmanned "pilot" balloons. Tracking the free-rising balloon with an optical theodolite—a surveying instrument that measures vertical and horizontal angles—enabled forecasters to compute wind speed and direction.

The program, dubbed "Pibal," is still in operation at 78 stations, gathering wind information for the lower four miles or so of the atmosphere. The balloons carry no instruments and are limited to good weather—clear or partly cloudy.

Attaching meteorological instruments to the pilot balloons was begun as early as 1909. But information was delayed and sometimes missing because the meteorograph had to be found after it parachuted to the ground.

By World War I, meteorographs were being flown by the novel method of fastening them to airplane wings. Kites remained in service on an ever-diminishing basis until 1932 when they were discontinued by the Weather Service in favor of airplane-collected observations.

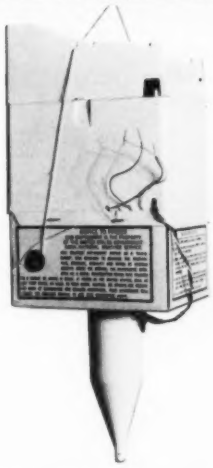
The airplane observation program, limited though it was, flew a stormy course. It was dangerous and expensive. It reached its peak in 1937. In just those few years, 12 pilots were killed. In foul weather, when observations were most needed, flights were often impossible.

Back in the 1920's, French and Russian meteorologists had successfully combined balloon-flown meteorographs with radio transmitters. By 1938, daily radio soundings of the atmosphere were an official Weather Service program.

By the beginning of World War II, the radiosonde replaced the airplane altogether. It provided meteorologists a safe, inexpensive way to make daily, "weatherproof," atmospheric profiles, thus accumulating large amounts of relatively error-free data for comparison and contrast.

As more and more radiosonde stations were added, the profiles formed a picture of the weather from coast to coast. More than 100 stations are now in operation. They make their observations simultaneously twice a day.

Return of the Radiosonde



Recovered radiosondes—about 25 per cent of the total flown each year—are mailed back regularly by alert, conscientious citizens. Serial numbers on the radiosonde tell where the radiosonde was launched, but most are returned with a friendly letter telling where and how it was found.

One classic letter a couple of years ago came from a not-too-remote area in Alaska. With superb tongue-in-cheek, the letter-writers described what happened when the radiosonde landed:

It seems that a large, ill-tempered moose, which was startled by the radiosonde's parachute, became so upset he pawed the ground so ferociously that he started a chain reaction—rabbits running, squirrels chattering, lynx spitting, foxes yelping, wolves howling, and snowbirds fluttering.

The by-now-thoroughly-upset Moose began running to escape the confusion. Head down and traveling full-tilt, the Moose thus managed to crash into the letter-writers' house and nearly demolish it.

A bill was duly enclosed with the letter. It had such interesting items as tranquilizers for Moose, tranquilizers for people, cost of new roof (shingles instead of dirt), cost of filling hole in wall (old rags), cost of filling hole in other wall (more old rags), building in new cabinets (to replace original orange crates), and on down to a fine paid for shooting Moose out of season.

The bill, totaling nearly $30,000, revealed its punch line at the very end with an item: "Less $25.00 (Received from Pawn Shop for Radiosonde)."

Man and the Wind

Many ceremonies have been created to aid in the important art of charming the rain. A large set of folklore also surrounds the sun, the moon, and the wind.

Early peoples believed they could make the wind blow or stand still. Such "magic" became part of the folkways for the simple reason that, at some time or other, it appeared to work. Chances that it would work again (50-50) were good enough to keep the practice going.

—The custom of throwing a knife at the wind to persuade it to go away is still sometimes used by some of the Breton, German, Slavonian, and Esthonian rustics.

—Herodotus described a war waged against the south wind.

—In ancient India, the priest confronted storms with club, sword, and fire, chanting magical incantations.

—To turn aside an approaching storm, a Cherokee wizard faced it and recited a spell. Gently blowing toward the direction he wished the storm to go, he "pushed" the storm there with his hand.

—Capture of the wind was believed possible. In the "Odyssey," Ulysses received winds in a leathern bag from the King of Winds. Proverbs 30:4 perhaps refers to this belief in its riddle: "Who holds the wind in his fist?"

—Finnish wizards sold wind to those in need of it. They enclosed the wind in three knots tied in a rope. Undoing the first knot brought a moderate wind, on down to the third knot, which presumably few untied since it would bring a hurricane.

—The tying of wind in three knots was a widespread magic, used in Lapland, Shetland Islands, and the Isles of Lewis and Man. In the Shetland Islands, certain old women were reputed to rule the storms. They sold winds in the shape of knotted handkerchiefs or threads.

—The Wind clan of the Omahas flapped their blankets to start a breeze to drive away mosquitoes.

—In New Guinea, two ways of starting up a wind were practiced: One was by blowing with the mouth, a very powerful magic. The other way was to strike a "wind-stone" with a stick—but lightly, so as not to start a hurricane.

—British Columbian Indians believed twins to be able to summon any wind by moving their hands.

—And what sailor today may not occasionally find the need to "whistle up the wind"?

A few radiosonde stations—nine scattered across the United States—report on air stagnation episodes. Air stagnation radiosondes ascend more slowly than regular radiosondes. They are flown when winds are slight or nonexistent and the presence of a dangerous temperature inversion is suspected.

A temperature inversion—warm air layered above cold air—prevents the normal rising of air from below. Instead, rising smoke, dust, and fumes strike the warm air layer and spread out like steam against a pot lid. If the inversion lasts long enough, undispersed pollutants can reach lethal concentrations, unless measures are taken to reduce the input.

The National Weather Service's regular radiosonde launches are part of the 800 daily around-the-world launches by cooperative stations under an international agreement with the World Meteorological Organization. Cooperative stations in the Western Hemisphere include eight in Mexico, nine in the Caribbean, four in Chile, one in Colombia, and an ocean station—a vessel roughly 200 miles east of Ocean City, Md., in service from August to about mid-April to warn against ocean-generated storms.

One of the benefits of upper-air observation programs is numerical prediction—a way of saying what the weather will probably be by application of mathematical equations. Another is simulation by computer of the circulation of the atmosphere of the entire globe—a way of applying equations on a worldwide scale.

With the further sophistication of weather science by rocket probes and weather satellites, there has been talk that the tiny radiosonde, dangling from its balloon, might be obsolete. Not so.

True, the modern geostationary satellite is a marvel of the age. It can track great storms, day and night, with ease. But it cannot detail what goes on at successive points in the envelope of air with the fascinating minuteness of the radiosonde.

The radiosonde is often the first warning that conditions may be right for tornado formation. It scouts the air ahead for fronts on the move and likely to clash. It tells of the peril of too much or too little—rain, snow, wind, cold, or heat. It also tells of days when the sun will shine and all's right with the world.

The radiosonde has accomplished a lot. But like most nearly forty-year veterans, it may be almost ready to hand its task to the next generation.

The next generation radiosonde may be a new design of the instrument itself, with a crystal-controlled transmitter. Also being developed is a low-density lithium battery. The radiosonde case is a new shape to house the new design. Expanded foam, such as styrene, is now being tested under simulated flight conditions for its suitability as casing material. Other improvements, such as tie-in with the upper-air minicomputer, will also give the radiosonde a faster and better information-return capability.

Our roving sentries in the sky are getting better all the time.

MONI
the little ship
a
unched
navy
DEPARTMENT OF COMMERCE
STATES OF AMERICA

The Monitor Marine Sanctuary

An Historic Ship Launches An Important Marine Program

BY WILLIAM J. BRENNAN

The wind, biting in its chill, sweeps in from the north, collides with the ocean currents rolling up out of the southwest, and whips the seas into 12-foot, white-capped waves. Off to the northeast, just where the dullness of the sky meets the grey ocean, a brilliant beam flashes on and off; Diamond Shoals light, the only evidence from 16 miles to sea that mankind exists. Small craft shun this area off Cape Hatteras in the winter and the occasional freighter, tanker or patrol boat has yet to pass through on this morning of January 30, 1975.

Beneath the surface, a 15-foot shark cruises through the harsh currents about the crumbling wreckage of a sunken vessel, and pokes its snout into the circular mechanism that extends from under the overturned metal hull. Then, flicking its tail, the shark swims out of sight. The remains of the U.S.S. Monitor, resting for 112 years in 220 feet of water, are disturbed only by the currents.

The blare of trumpets overwhelms the normal quiet in the cavernous lobby of the Department of Commerce in Washington on this Thursday morning, the 30th of January. The 100 or more men, women and children, sitting expectantly before the brightly-lighted table and backdrop, stir with anticipation. A Navy honor guard presents the colors. The strains of the National Anthem bounce off the high ceiling, roll out onto sunny 14th Street, and cause pedestrians to pause momentarily. Dr. Robert M. White, Administrator of NOAA steps to the podium: "It is a great pleasure to welcome you here today to share a moment of history . . ."

One hundred and thirteen years to the day the U.S.S. Monitor was launched in Brooklyn, N.Y., she has reclaimed her heritage as one of the more sacred ships of the U.S. Navy. "The Monitor occupies a place in history never to be accorded another American ship," Secretary of Commerce Frederick B. Dent proclaims. "The U.S.S. Monitor was truly the forerunner of a new era of naval warfare," states Vice Admiral Edwin B. Hooper, Director of Naval History. Now another star is added to her crown: her grave becomes the Nation's first Marine Sanctuary.

Famous "battle of the ironclads" March 9, 1862 (above left) was a draw, but changed the course of naval shipbuilding. (Photo courtesy Naval History Division.) Below, Secretary of Commerce Frederick B. Dent designates Monitor resting site as first Marine Sanctuary, with (l. to r.) Mrs. Grace J. Rohrer, Secretary, North Carolina Department of Cultural Resources; Robert Knecht, NOAA; Dr. Robert White, NOAA Administrator; Vice Adm. Edwin B. Hooper, USN, Director, Naval Historical Center; and John Newton, Duke University Marine Laboratory.

Designation of the Monitor site as a Marine Sanctuary may be a truly unique moment in history. The Marine Protection, Research, and Sanctuaries Act of 1972, under which the Secretary of Commerce, with the approval of the President, is authorized to designate Marine Sanctuaries, is at heart a conservation bill. Future sanctuaries, it is likely, will be based on environmental or recreational rather than historic values.

There is no heritage upon which Marine Sanctuaries can rest, no record on which to measure their contribution. But the potential is tremendous, viewed in terms of the interrelationship between the Marine Sanctuary program and those other conservation activities conducted by NOAA under the Coastal Zone Management Act, the Marine Protection, Research, and Sanctuaries Act, the Marine Mammals Protection Act, the Fish and Wildlife Act, and other legislation.

In this montage, according to Secretary Dent's remarks at the Monitor designation ceremony, "we have what amounts to a substantial body of law spelling out a major national environmental obligation;" a commitment to the proposition that "as demands for the world's marine resources increase and intensify, the obligation and the opportunity to provide for balanced, well-managed, environmentally sound use of these resources go hand in hand."

The concept of a Marine Sanctuary is that areas of the ocean and coastal waters have values vital to a balanced use of the sea's resources which should be protected and/or restored for their own merits, according to Dr. Robert R. Kifer, Marine Sanctuaries Coordinator for NOAA's Office of Coastal Zone Management. Sanctuaries, he points out, are not intended to prevent legitimate uses of the sea, but to protect unique areas.

"There are areas of the ocean that should be preserved or restored for various purposes," Dr. Kifer explains, "and once a purpose for preserving a given area has been determined, the regulations for that sanctuary should not reach beyond controlling activities that would interfere with, or destroy the values of, the primary purpose. Thus, multiple use should be encouraged to the extent it is compatible with the purpose of the sanctuary."

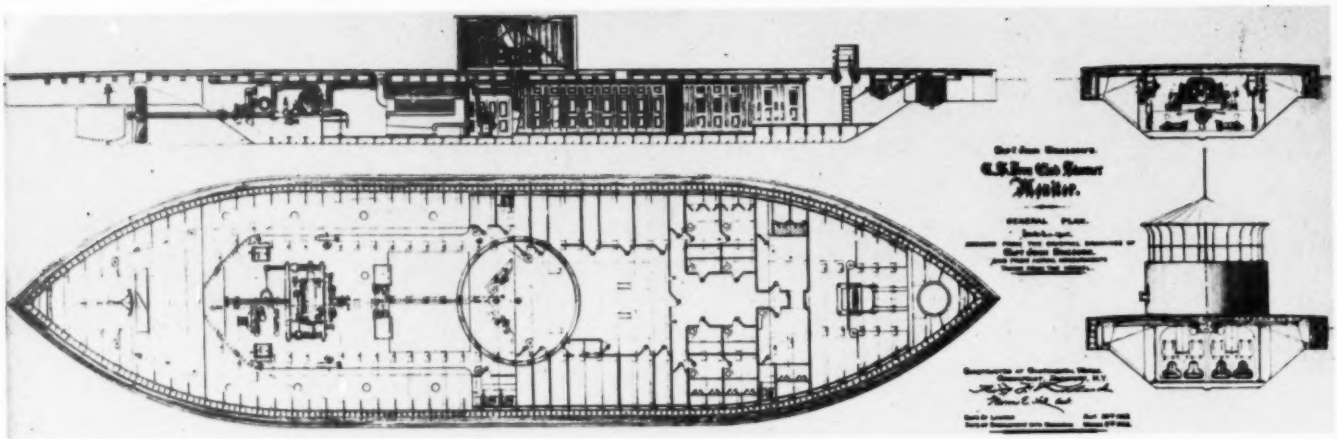
While the Monitor Marine Sanctuary is in a class by itself because of the ship's historic significance and the contribution its design—still not totally understood by contemporary naval designers—made to marine architecture, more relevant to modern life is a sanctuary such as that proposed for the barrier reefs off John Pennecamp State Park near Key Largo, Florida. There are the nation's major concentration of living coral reefs; barrier reefs helping halt erosion and which, because of their unique nature, are major tourist attractions as well as of great interest to marine scientists.

The scientific value of the Key Largo reefs is poorly appreciated by the layman, with the result that existence of the reefs in a living state is imperiled. Divers walk upon the coral, killing it. Recreational boaters anchor on the reef, damaging it. Souvenir hunters pull off pieces of coral grown over a century's time to grace a mantel at home.

The nomination of the reefs as a Marine Sanctuary is being evaluated and processed. If designation occurs, Dr. Kifer says, modest restrictive regulations would be put into effect. Skin divers will still swim through the coral, but not tread upon it; boats can cruise above the reefs but not drop anchor upon them. And fishermen will still be able to fish the area but must respect catch limits within the ability of the fish to reproduce.

This is precisely what the Act calls for; ". . . preserving or restoring areas for their conservation, recreational, ecological, or esthetic values."

Commonly known as the "Ocean Dumping Act" (the major sections of it relate to dumping of materials into ocean waters), the Act gives NOAA, through delegation by the Secretary of Commerce, authority over waters as far seaward as the outer edge of the Continental Shelf, and on the land side wherever the tide ebbs and flows. (Additionally, the Great Lakes and their connecting waters fall under the Act's jurisdiction.) Requiring the usual public hearings and participation prior to designation of a sanc-



Construction drawings of "cheesebox on a raft" USS Monitor (top). Left, three descendants of Monitor crew members, at ceremony designating first Marine Sanctuary: (l. to r.) George M. Worden, Fred Keeler Brown, and Rear Adm. Schuyler Pyne, USN (Ret.). Above, Secretary of Commerce Frederick B. Dent points to Monitor model on display at ceremony.

tuary, the Act may be unique in that any individual or organization can nominate an area as a sanctuary. In the case of the Monitor, it was nominated by North Carolina Governor James E. Holshouser, Jr. (a fellow North Carolinian found the ship's final resting place; John Newton, Marine Superintendent of Duke University's Marine Laboratories). But any individual, through concern for the nation's ocean resources or for a number of other purposes, can make a nomination for a Marine Sanctuary.

This is not to say that every area nominated will ultimately be designated. Probably not, in fact, current experience indicates. Several nominated sanctuaries have failed to reach the designation stage because it was found the problem they addressed could be solved in a better way.

Crystal River in Florida is a good example. A portion of it was nominated by the president of the Crystal River Protective Association, a citizen concerned that Florida manatees—seal-like creatures declared an endangered species—were being injured or killed by boats during those months the mammal wintered in the warmer waters of the river.

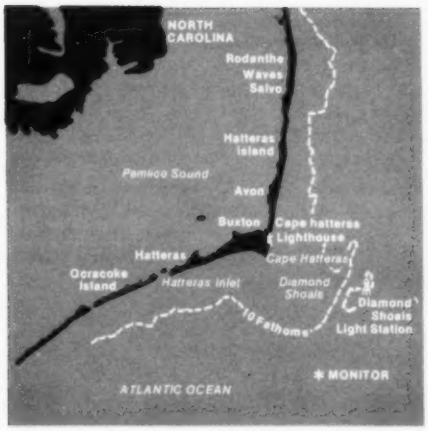
The manatee swim near the surface, and frequently are struck by boats, and often fatally injured. The association president recommended that through establishment of a Marine Sanctuary, a speed limit be imposed upon craft using the river during those months it is inhabited by the manatee.

Upon receipt of nominations, Dr. Kifer routinely reviews other pertinent legislation to determine if it might be applicable. In the Crystal River case he found the manatee could be fully protected under sections of the Marine Mammals Act and the Endangered Species Act administered by the Department of the Interior. Communication with Interior found officials there happy to cooperate, and it presently appears the manatee will be protected by modifying existing regulations.

The proposed—and rejected—Crystal River Marine Sanctuary underscores a key point in the legislation; that sactuaries are not intended to be a marine wilderness where man cannot enter. As defined by Congressman Thomas Pelly at the time the Act was under Congressional consideration, designation of an area as a Marine Sanctuary "will insure very simply a balance between uses."

Then-Congressman Hastings Keith, during the same discussion, put his finger on a point which subsequently has caused confusion. "I must admit," the Massachusetts Representative said, "that the word 'sanctuaries' carries a misleading connotation. It implies a restriction and a permanency not provided in the title itself. Title III (of the Marine Protection, Research, and Sanctuaries Act) simply provides for an orderly review of the activities on our Continental Shelf. Its purpose is to assure the preservation of our coastal areas and fisheries . . ."

As viewed by Dr. Kifer, the preservation



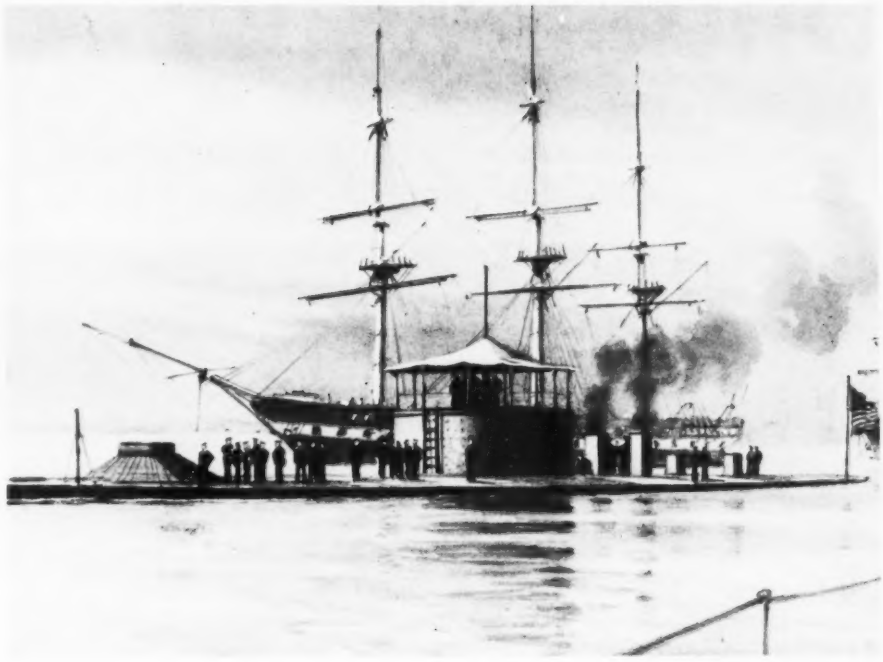


Photo mosaic shows famed Civil War gunboat as she now lies, upside down off North Carolina coast, with arrow designating her revolving turret, which broke off during sinking (top). Above, chart of Monitor site. Right, painting of the Monitor at port before the battle (Photo courtesy Naval History Division, Navy Department).

afforded by a Marine Sanctuary could come in any of six varieties; preservation of habitat, species, research, recreation, esthetic, or unique areas; each with a somewhat differing goal.

Habitat areas could be designated as Marine Sanctuaries for the preservation, protection and management of essential or specialized marine or estuarine ecosystems which are either one-of-a-kind or representative of a given type. Examples that come readily to mind are coral reefs, hypersaline lagoons, bays, and sounds, with the emphasis on protecting the wellbeing of the living resources so as to maintain a healthy, continuous and balanced population.

Species areas would focus on protecting selected species in an area during part or all of its life cycle. The emphasis would be on maintaining sufficient genetic resources to insure continued reproduction of a species at a level sufficient to help keep the population in its ecological niche over its present geographic range.

Research areas would be for precisely that purpose; areas in which to conduct baseline studies on the natural ecology to ascertain the impact of a given man-made activity. In those areas which have been studied historically, a Marine Sanctuary could provide assurance that the on-going research would have long-term continuity.

Recreation and esthetic areas would be akin to National Parks and National Seashores, established primarily to preserve areas for recreation or for their natural beauty. It is anticipated, in fact, that some Marine Sanctuaries of this type will augment existing National Parks and National Seashores.

Unique areas would be, as in the case of the Monitor, for the protection of one-of-a-kind, or nearly one-of-a-kind, geological, oceanographic, or living resource features, which could have historic, cultural, economic, physical, chemical or biological value or use. Such features as the high tides of the Bay of Fundy, the salt domes of the Gulf of Mexico, or historic artifacts are examples.

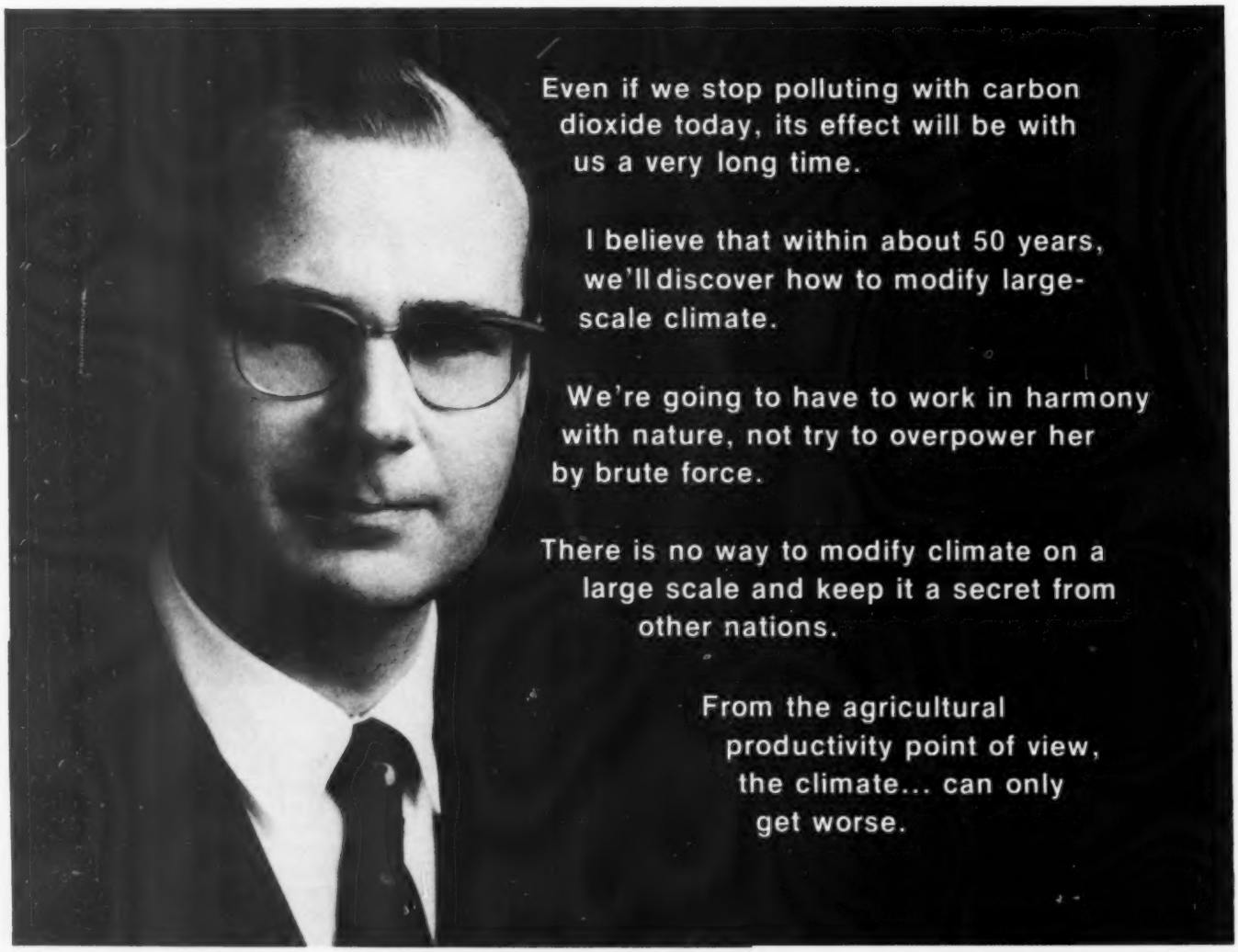
In enumerating the various types of Marine Sanctuaries possible, Dr. Kifer stressed again the intention that sanctuaries not exclude any activities except when they conflict with the protection being provided. "Often," he said, "the seascape we enjoy sitting and looking at includes not merely sky, sea and surf dashing on rocks, but also a familiar fishing boat at work or sailboats running downwind; witness the many works of art which feature labors of the sea."

No one knows how many sanctuaries there ultimately will be. But, as Secretary Dent emphasized in his remarks at the Monitor Marine Sanctuary designation ceremony, "as demands for the world's marine resources increase and intensify, the obligation and the opportunity to provide for balanced, well-managed, environmentally sound use of these resources go hand in hand." It is to this end that the Marine Sanctuary program is devoted.

A distinguished climatologist discusses one of our greatest enigmas

World Climate: Major Changes Under Way?

DR. J. MURRAY MITCHELL, JR., WAS INTERVIEWED BY EDWIN P. WEIGEL



Even if we stop polluting with carbon dioxide today, its effect will be with us a very long time.

I believe that within about 50 years, we'll discover how to modify large-scale climate.

We're going to have to work in harmony with nature, not try to overpower her by brute force.

There is no way to modify climate on a large scale and keep it a secret from other nations.

From the agricultural productivity point of view, the climate... can only get worse.

Q—Dr. Mitchell, there have been many articles in the popular literature during the past year suggesting that an ominous global cooling trend is under way which will cause mass tragedy for mankind. Do you agree?

A—The world does seem to have been cooling off in the past 20 years or so, but we shouldn't count on this cooling trend—ominous or not—continuing for a long time in the future. It might very well give way to a warming trend at any time. There is no way we can tell whether it will or not. So we can call the cooling trend ominous in the sense that, if it continues long enough, it will eventually get us into all kinds of trouble. But we should keep in mind that climate trends are typically rather ephemeral and that this trend is not necessarily any different than innumerable others that mankind has survived.

Q—How can the man-in-the-street tell which weather prophet to believe? Is there some sort of high-level scientific-advisory panel that evaluates these predictions for the Federal Government, so that it can, in turn, advise the public?

A—The Government does not have a mechanism for responding officially to pronouncements made by "weather prophets." It might be more appropriate for the American Meteorological Society to step in with a mechanism for doing this.

Q—How was it established that there has been a cooling trend?

A—Such trends of temperature are established simply by averaging together conventional weather data over many years for large parts of the Earth. It's been done for the whole world. I worked on this kind of thing with Professor Hurd Willett of the Massachusetts Institute of Technology when I was an undergraduate student of his back in 1950. The data we analyzed together then was from about 1880 to 1950. I joined the Weather Bureau in 1955 and in the early 1960's brought that same study up to date through 1959. By that time it was clear that what before had looked like a continued warming trend for the world had turned the corner in the 1940's, and we were definitely cooling off. Other people have carried on such work beyond where Willett and I left it. They find the cooling trend continuing, but possibly faltering in the past few years.

Q—Are all of these investigators using basically the same observing stations?

A—Yes, there tends to be a huge overlap in stations that different people choose for these kinds of studies, because we're all looking for long-record stations that haven't been moved around very much over the years. And there just aren't very many stations throughout the world that meet these criteria. So, different people looking at the problem naturally gravitate toward the same selection of stations and data.

Q—How far back do the records go?

A—In parts of England and Europe, for example, you have very good records going back two or three centuries. But for the Earth as a whole, or even the Northern Hemisphere, you can't find a very adequate geographical sampling of stations until the last century—about 1880, roughly. Before 1880 you simply don't have adequate meteorological records to cover the Earth. Even after 1880, the coverage isn't too good, but you can at least begin to speak with some confidence about global climate trends.

Q—This is one of your big problems, isn't it, the relatively short span of your records?

A—Yes. We would like to go back about 10 centuries, at least, in order to make sure how to interpret what we've been observing in the past century, and what might be in store for us in the next century.

Q—During this cooling trend, how much has the temperature actually dropped?

A—Since the 1940's, the average temperature of the Northern Hemisphere has fallen about three-tenths of one degree Celsius, or one-half of one degree Fahrenheit.

Q—Does that small a change really produce significant effects?

A—Well, although it does seem to be much too small a change to get very excited about, it should be emphasized that when the average temperature of the Hemisphere changes even a little bit, usually there are much larger changes taking place in certain parts of the Hemisphere, especially in the Arctic and sub-Arctic regions. I think it's quite clear that's what's happening.

Q—Is this change enough to begin worrying about a new ice age?

A—If the temperature of large parts of the Earth fell by two or three degrees, this would probably be enough to start building up the ice sheets, the way the last ice age began. That's a lot bigger change, though, than we're likely to see any time soon.

Q—In what areas has the cooling trend been most noticeable?

A—Generally speaking, the Atlantic sector of the Arctic has cooled the most. Much of the United States, by the way, has gotten cooler over the past 15 years by more than the global average. Summers have become about one or two degrees F. cooler, and winters as much as four or five degrees cooler, in some places. The greatest cooling in the U.S., generally speaking, was in the

Dr. Mitchell, who maintains his own weather station at his home in McLean, Va., adjusts cables supporting the instrument tower.

Appalachian area—east-central United States.

Q—Do you think this global cooling trend is related to the drop in food production around the world?

A—Related, yes, but probably not very directly so. More important than temperature are the rainfall changes, and the changes in length of the growing season.

Q—Some people say there's a relationship between cooling and drought.

A—Well, you can't assume that cooler always means drier. Many areas that have cooled have gotten wetter. The infamous Dust Bowl drought of the 1930's came at a time when the world was nearly as warm as it has ever been in this century.

Q—Is the cooling trend linked to drought in the sub-Saharan region of Africa, as has been suggested?

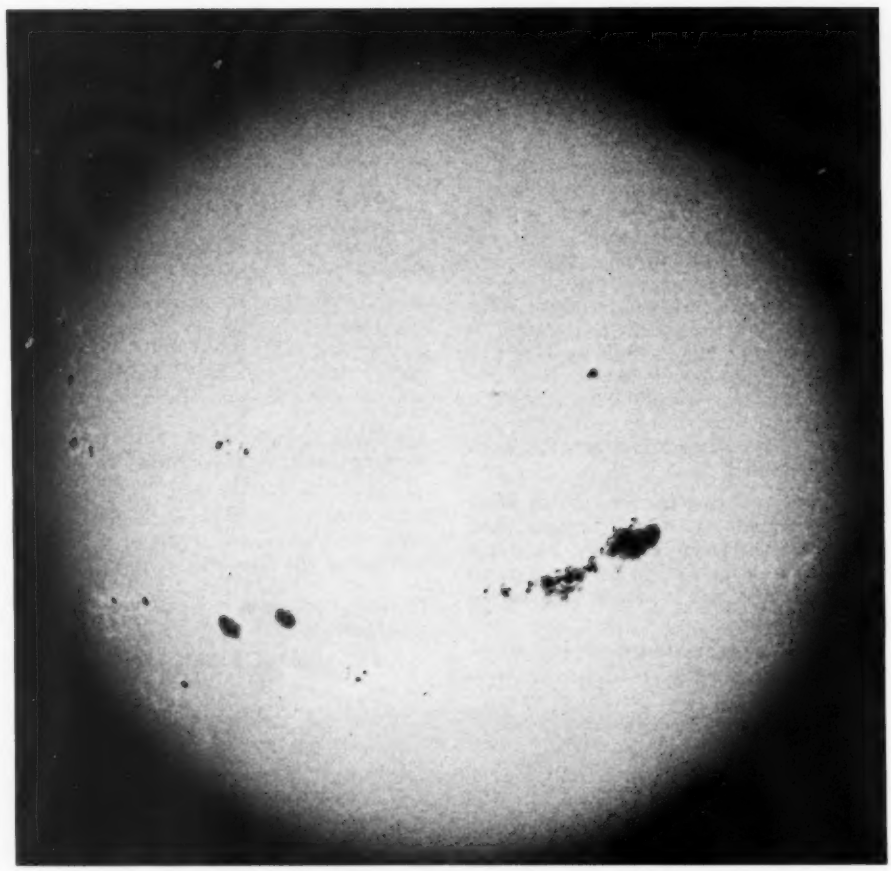
A—I think the cooling trend is probably consistent with all kinds of anomalies around the world—more rain here, more drought there, unusual heat one place, unusual cold another. But the locations for these kinds of extreme events will always be shifting. A drought in the Sahel of Africa will not happen every time the Earth is in a cooling phase. Nor does a drought in the Sahel necessarily mean that the Earth is cooling off. There's no one-to-one relation between the Sahel and temperatures elsewhere in the world. But there is some theoretical justification for saying that whenever the polar regions are relatively cold, as they are today, you will get more variability of climate in middle and lower latitudes.

Q—Why is that?

A—Because the circulation of the entire atmosphere is working harder, trying to warm up the polar regions. The atmospheric heat engine apparently accomplishes this by increasing the meanderings of the circumpolar vortex—the great planetary wind that flows generally eastward around the globe. This wind always undulates in enormous intercontinental meanders, but when the polar regions are colder than normal, the undulations become larger, producing greater extremes of weather underneath. With these larger excursions of the wind, there's a tendency for weather systems to get cut off, and not to move along as rapidly as they usually do in the prevailing west-to-east flow. In some places the result may be drought; in others, a whole series of floods. But not necessarily the same unusual weather in the same place from one month to the next, or from one year to the next.

Q—Are there records to support the contention that extremes of weather are becoming more common?

A—Yes. A recent study by the Japan Meteorological Agency, based on weather observations from about 120 observing stations around the world, showed that weather extremes in the middle latitudes have indeed become more frequent in the past 30 years. This increasing variability would be quite consistent with cooling in the Arctic.



Spots on the sun are revealed by the use of a camera fitted with a special filter.

Q—How about predictions that the U.S. is in for another drought reminiscent of the 1930's because droughts seem to come in 20-year cycles. Do you agree?

A—I agree to the extent that I'm concerned there might really be a 20-year cycle, without being able to prove it. I see some circumstantial evidence for it, but it's not altogether convincing.

Q—What kind of circumstantial evidence?

A—Purely statistical, based on the timing of droughts in the U.S. high plains since the mid-19th century, which showed a tendency to recur about every 20 years.

Q—What about the hypothesis that droughts are related to sun-spot cycles?

A—Well, it has been pointed out that the timing of droughts in the high plains appears to have paralleled the double sunspot cycle. Sunspots recur in 10- or 11-year cycles—more often 10 years in this century. Every second time we get lots of spots on the sun, the period that follows tends to be paralleled by a drought in the high plains.

Q—Why every other time? Why not every time, do you suppose?

A—One idea is that it may be linked to something happening on the sun which alternates from one cycle to the next. We know that the magnetic polarities of the spots reverse, so that they come back to their starting point every second cycle. These changing magnetic polarities may not mean anything at all to radiation impinging on Earth. But they do occur, and cause speculation.

Q—Just what are sunspots anyway?

A—We don't know precisely. We do know they are relatively cool spots—dynamic features, with lots of things going on, but still relatively cool. They form at the start of each cycle in the sun's low latitudes and work toward the poles. When they reach the middle latitudes they're usually more numerous, and that corresponds to a peak in the cycle.

Q—Then if a sunspot-drought correlation exists, we're about due?

A—Yes, if the correlation is real. In the last century, every second sunspot minimum more or less coincided with a major drought in the U.S. Such a sunspot minimum is occurring right about now, and will reach its lowest point in a year or two—it's a very protracted minimum.

Q—Are there weaknesses in the sunspot-drought hypothesis?

A—Yes. The weakest link is that there is no physical mechanism we can think of which convincingly explains why a change in spottedness on the sun should be followed by any important change in the Earth's

The dust bowl of the 1930's is the type of disaster that farmers fear most. Despite predictions that another one is due, there is evidence that the so-called "20-year cycle" may not be real.

weather. The second weakness is that the line-up of droughts into what looks like a regular cycle—whether connected with sunspot minimums or not—doesn't appear to go back very far. It's a fact of only the past 100 years of drought history that we know anything about. The "cycle" probably didn't exist before that. We have tree-ring data from the high plains—Nebraska and South Dakota—which reflect the timing of droughts, and these don't support at all the notion of a 20-year cycle in earlier centuries. Tree rings going back to about the 16th century reveal the average interval between major droughts was much greater then. Also, the interval between droughts was very irregular then.

Q—Then you discount the sunspot-climate hypothesis?

A—In this sense: Although changes in solar activity do affect weather—and there is mounting evidence that they do—these effects are very small in relation to effects arising from other sources. So the idea of using the sunspot cycle as the sole guide to past and future changes in climate just isn't the way to go. There are too many other things affecting climate.

Q—How about longer-term changes in solar activity?

A—It remains to be seen if the sun's activity varies significantly over periods longer than the 10- or 11-year cycle. It's only once in a century, for example, that the 10- or 11-year sunspot peak gets very large in amplitude. We just went through a maximum-amplitude phase in the last three peaks: 1948 was large; 1958 was largest in recorded history; '68 was smaller; and the next one, not due until at least 1980, is expected to be very small.

Q—Could these peaks indicate greater heat output from the sun?

A—Perhaps. We don't know. We don't have reliable measurements. Those we do have go back to the turn of the century, when Charles Abbot of the Smithsonian Institution began trying to measure the "solar constant" on a continuing basis. They tell us that, if there really are systematic changes in solar output related to sunspot cycles, the magnitude of those changes is certainly less than one per cent. Such changes don't show up in the data we have.

Q—How much change in solar output would it take to affect Earth's climate?

A—Even if the magnitude of change were as little as one-tenth of one per cent, that would be enough to explain such things as the fluctuation of a few tenths of a degree in global mean temperature. To measure a change that small is impossible with observations from the ground. There is a crying need for such measurements.

Q—How would you get them?

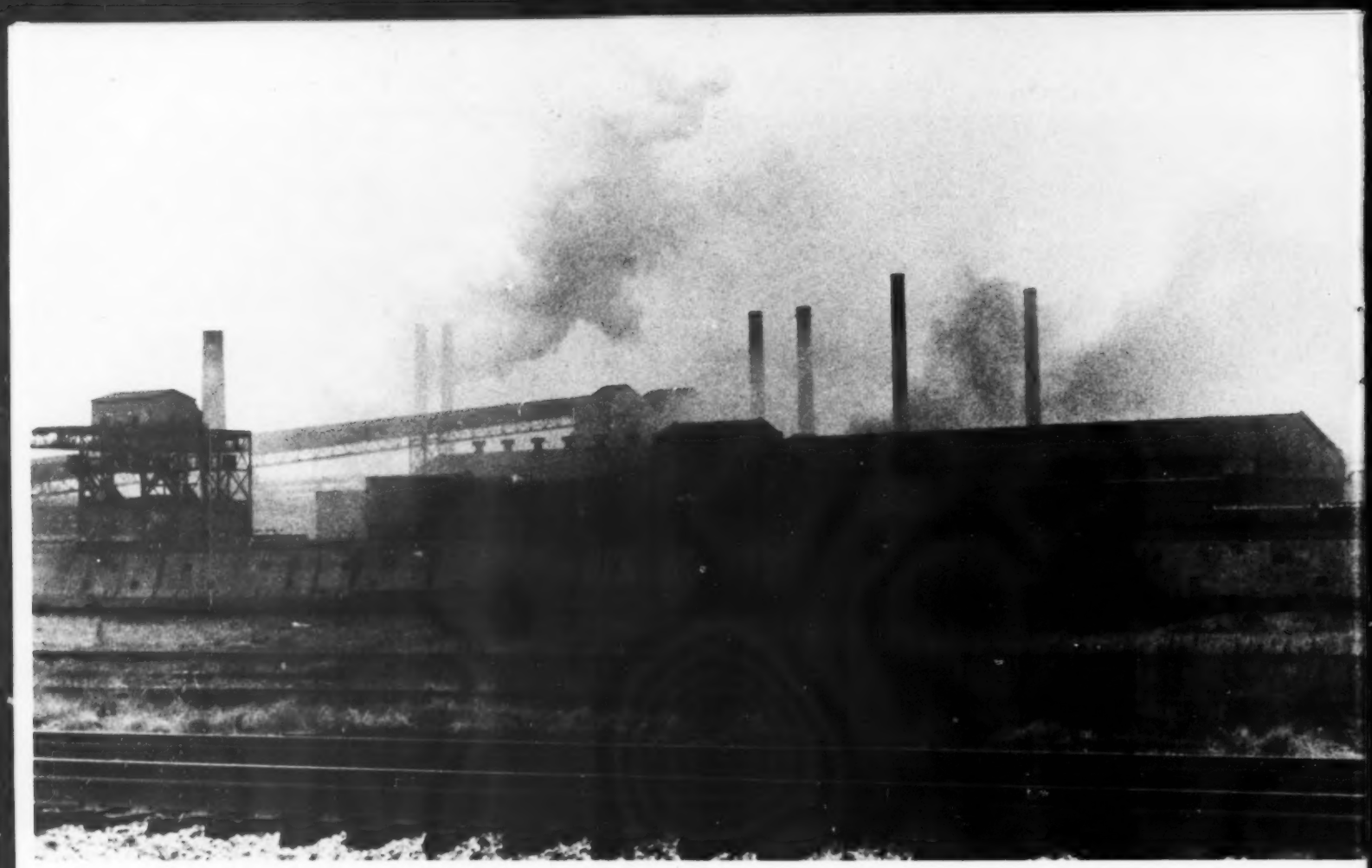
A—There is reason to believe measurements to an accuracy of one-tenth of one per cent could be acquired by mounting an appropriate instrument on a satellite. But to date there has been no attempt to put such an instrument into orbit, despite the fact that we have had such instruments on the drawing boards for ten years now. I'm convinced that it will get done fairly soon. You wouldn't need a single satellite with an instrument staying in orbit for a long period of years. As long as the performance of the instrument is reproducible from one satellite to another, you could do it with a succession of shorter-mission satellites, as an "add-on" to space-observing programs already in the works.

Q—Do you foresee a day when we'll be able to predict long-term changes in weather and climate?

A—I think within the next 10 years we will have developed a capability for projecting month-by-month and season-to-season weather developments with appreciably more skill than we do today.

Q—You mean the 30-day and 90-day outlooks now being issued by the Weather Service's Long Range Prediction Group?

A—Yes. I believe those will have a lot more than the marginal value they have



Increasing amounts of smoke and dust, carbon dioxide, and heat are being introduced into the atmosphere by man's activities. All of these have some effect on weather.

now. But if you're talking about predicting what will happen several years in the future, or several decades, I don't think it's at all clear how soon we'll crack that nut.

Q—Do you think it's impossible?

A—No, I'm an optimist. I think eventually we will be able to predict climate into future decades or centuries, at least to some extent. But a great deal will depend on the success with which we improve both the theory and observation of the atmosphere and the oceans. The problem is extremely complex. We don't yet have an adequate theory; and we certainly don't have an adequate observation system for tracking all the elements of our environment that are likely to govern long-term climate changes.

Q—Will development of numerical models of the atmosphere be a big factor?

A—Yes, I'd say the work of the Geophysical Fluid Dynamics Laboratory under Dr. Joseph Smagorinsky is going to be the guiding light. The Laboratory is trying to develop a numerical model of the entire climate system, which involves not just the atmosphere but also the oceans, the ice on the oceans, and other things which influence climate over a long period. I might add that the main thrust of what we call the "second objective" of the Global Atmospheric Research Program (GARP) is also in this direction. Many institutions, both in the U.S. and abroad, will have important roles to play in all this. So will the World Meteorological Organization and other international organizations.

We know in a vague way what is required in a mathematical model of the atmosphere—that is, what should go into it to provide us with a real understanding of climate change. But having vague feelings is not enough. We've got to have very specific understanding of the detailed mechanisms involved in climate change. We have to develop a much better understanding of how clouds and their life cycle can be simulated in atmospheric models. Also a much better understanding of ocean behavior. It's going to take many years to satisfy ourselves that we have all that nailed down adequately.

Q—Will this call for a vastly improved data-collection system, from a lot more places?

A—It isn't necessarily true we'll need more points of collection, or more observations of the conventional sort. What we're quite clear on is that we'll need more information on things that we are not now measuring very well at all. I think the most critical need is for further measurements in the surface and upper layers of the oceans . . . how much heat they are carrying around and how readily they are capable of exchanging heat with the atmosphere . . . from which depths the heat is coming . . . things of this kind. The oceanographers are well aware of our concern with this. And they are pitching in to try to conceive of observational systems to get this information on an efficient operational basis.

Q—Will satellites do it?

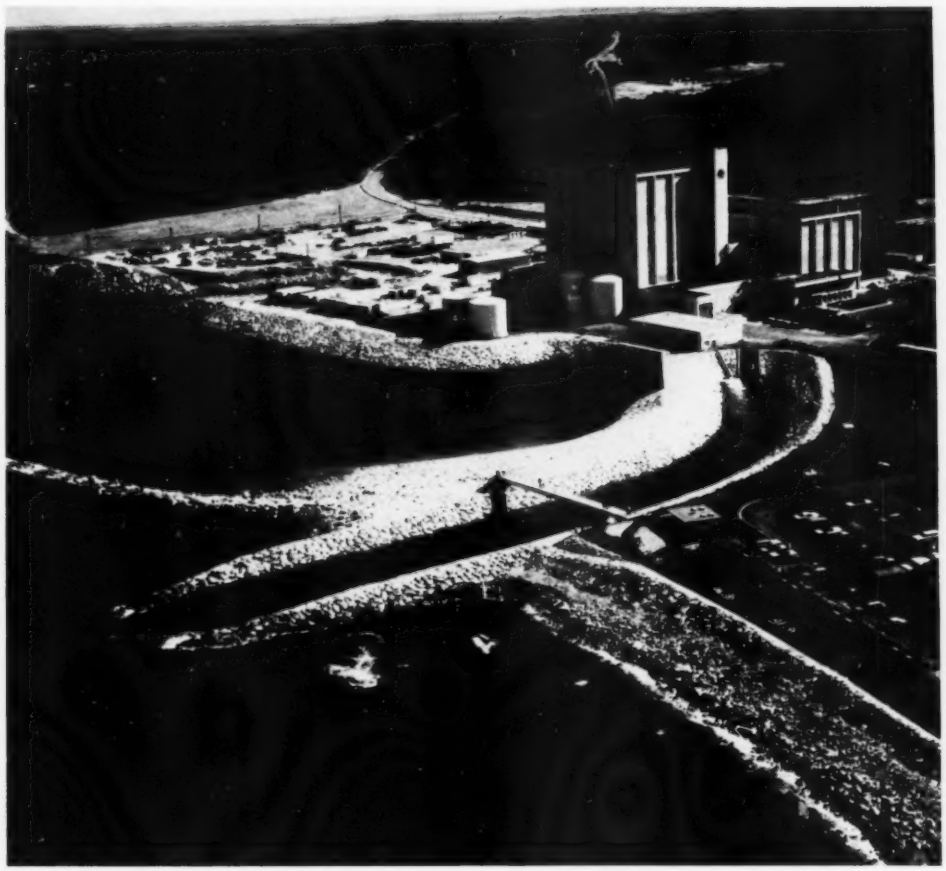
A—Probably not altogether. It would take satellites plus either buoys or special fleets of ships or aircraft, or something of that nature. We've got to go under the sea surface with something and measure things there. We can't get the whole story from satellites, except, of course, we might need communications satellites to relay the data collected from other sources.

Q—Are man's activities affecting climate?

A—Yes. On a local scale, we can see ample evidence of this already. Urban growth, for example, has been affecting climate from the first moment people started building settlements. The bigger cities get, the warmer they get, and the more they apparently tend to cause local increases in rainfall.

Q—How about larger-scale effects?

A—I think the answer to that has to be a qualified "yes." There are reasons for believing—theoretical reasons if nothing else—that man's activities should in various ways be starting to affect large-scale climate to a significant degree. But that's not the same thing as saying precisely what those effects are. And it's not the same thing as turning



Heat generated by all kinds of power plants may ultimately become the most serious man-made effect on the environment.

to the observations of the atmosphere and saying, yes, here we see confirmation of this effect or that.

Q—What are some of the man-made effects that might be taking place?

A—If we look at the amount of carbon dioxide that has been released by the burning of fossil fuels since the dawn of the industrial revolution, we can measure carbon-dioxide levels now and say with some confidence that there's about 10 or 12 per cent more in the air now than there would have been if man had never been around.

Q—And the effect on climate?

A—Even though this carbon dioxide is only a trace substance in the atmosphere, it has a very strong absorbing effect on thermal radiation—the kind of heat radiation trying to escape from the earth at night, to cool things down after a hot day. So, other things being equal, the presence of more carbon dioxide in the air impedes cooling and tends to warm the climate. It's like putting a sheet of glass over yourself and trapping the sun's heat passing through, as in a greenhouse.

Q—It would seem then the earth should be getting steadily warmer. Why isn't it?

A—Our understanding of the carbon-dioxide/greenhouse effect is what you might call only a first-order rationale. One of the things this rationale doesn't take into account is that if carbon dioxide really is warming the earth, it is also pumping more water vapor into the air, and thereby it might be increasing cloudiness in the atmosphere. Since clouds are white, the increased cloudiness will reflect back more of the sun's heat, and counteract the warming. So, all things considered, it may turn out that the increased carbon dioxide is not having as much of a warming effect as our first cut at the problem would suggest. Answering questions like that is one of the things climate models will do for us eventually.

Q—We hear about increased "dust" in the atmosphere, man-made or otherwise, having a cooling effect by reflecting the sun's energy back into space . . .

A—Right. There are several points to consider here. First, observations have not yet established beyond a doubt that the dust content of the air is increasing, worldwide, because of man's activities. On the other hand, we know from source inventories that more dust is getting into the air than nature alone can provide. So it seems you've got to conclude the dust load in the air has increased, even if you can't measure it. If this sounds contradictory, it simply means that the dust is not getting very well distributed, and that most of it is getting rained out within a few hundred miles of the place of entry, without having a chance to affect climate very much at a distance.

Q—Where does this man-made "dust" in the atmosphere come from?

A—There are three primary sources. One is fly ash and smoke, as from fires and smokestacks. The second is dust from the earth's surface, like dust raised when you till the ground in windy weather—which you might call man-stirred dust rather than man-made. The third is gases that we put into the atmosphere, such as sulfur dioxide, which do not start out as dust, or particles, but which become particles under the action of sunlight and in the presence of other naturally-occurring materials in the air.

Q—Then you can get particles from what starts out as an invisible exhaust from an automobile, for example?

A—Yes, very much like the smog over some of our cities. But the particles, or aerosols, aren't necessarily solids. Some of them may be sulfates or nitrates that have gotten into aqueous solution in cloud droplets. The chemicals are hygroscopic so they would cause the cloud droplets to grow much larger than they would otherwise, thus lowering the visibility.

Q—Presuming that both the carbon-dioxide/greenhouse effect and the dust/cooling effect are at work, which do you believe ultimately will be the more important?

A—Before answering that, let me point out that what I said about the carbon-dioxide/greenhouse effect may also be true about the dust/cooling effect. It, too, might be self-defeating, except the other way around. Particles are probably trying to cool the climate. We don't really know this for a fact yet. But anything that robs the surface of solar radiation, as particles do, is also likely to decrease evaporation and may therefore decrease cloudiness to let in more solar radiation, which would offset the cooling you start with.

So with both effects there's a possibility of a tendency toward self-defeatism.

But as to the relative importance of the two things, assuming they are at work in opposing directions, I would put my bet on carbon-dioxide/warming as being dominant, for two reasons. First, the cooling effect of particles is probably less than we have calculated it to be in the past, because of improper assumptions or incomplete modeling. Second, I think it will be a lot easier to clean up particles if and when we decide it's important to do so. Were we to stop putting dust in the air right now, this cooling effect would cease in a matter of days, because the particles don't stay in the air longer than that. But the carbon dioxide—what we've already put into the atmosphere—will stay there for decades after we've stopped burning fossil fuels. In fact, it will take centuries to remove that carbon dioxide. So even if we stop polluting the air with carbon dioxide today, its effect will go on for a very long time.

Q—Would you expect a permanent change in the Earth's climate?

A—There's a possibility of that, but not a certainty by any means. However, if the

An Alaskan glacier typifies the appearance of much of the Earth during the ice ages.

atmosphere warmed up very much, you would probably melt all the floating ice in the Arctic Ocean. Farther down the road from that, you might start eating into the Antarctic ice cap and the Greenland ice cap. And there's a very good question whether or not, if you removed the ice from the Arctic Ocean, the climate might respond in such a way as to prevent the ice from ever reforming. If you lost the ice from the Arctic Ocean and never got it back the climate of the whole Earth might change. We don't know this, but it very well might.

Q—How?

A—The higher latitudes would certainly be warmer, but not necessarily more livable. If the ice weren't there to limit the heat flux out of the Arctic Ocean, enormous cloud masses or dense fog layers would probably develop to do that job, and we might end up with a large-scale increase of cloudiness over the polar regions generally, mostly in winter. Also, storm belts might shift to higher latitudes because of the redistribution of heating in the polar regions and new storm belts might appear in lower latitudes. There might be undesirable increases or decreases of rainfall in food-growing areas. The whole distribution of world population might be under pressure to change, with all sorts of geopolitical consequences. So you can't assume that warmer polar regions are necessarily going to be a good thing.

Q—Are there any other activities of man that may be affecting climate?

A—Yes. One that will become of great importance, presumabily by 100 years from now, will be the fantastic amounts of heat poured into the atmosphere—most of it from power plants.

Q—Waste heat from nuclear power plants?

A—Any kind. It's worth emphasizing that virtually all energy that man uses, whatever its source, gets converted into heat in the process of being used. So it's not just waste heat thrown away at a power-generating plant; it's the heat value of all energy produced, whether usefully employed or not.

Q—This, too, seems to make an ultimate warming effect more likely, doesn't it?

A—Yes. This would augment carbon-dioxide/warming and it could end up being the most important source of warming of all. If recent global trends of economic and industrial growth were to continue another hundred years or more, then the heat released by man would approach the same order of magnitude as the heat coming from the sun, on a worldwide average basis. But to extrapolate an exponential growth for another hundred years on the basis of recent history would be folly, I think.

Q—Some people say that, because there is a distinct possibility of inadvertent weather modification, we should for that reason alone think about ways of changing the weather to meet our own needs. Others see this as just one more potential for global warfare, with hostile nations using the latest in science and technology to bring down bad weather on their enemies. What do you think?

A—I believe that within about the next 50 years we'll discover how to modify large-scale climate either way . . . hot or cold . . . wet or dry. But it is going to be very difficult to modify climate in a made-to-order fashion—that is, for temperature or rainfall to be increased X per cent here and decreased Y per cent there. I think that is very unlikely. The atmosphere just won't cooperate to that degree. We're going to have to work in harmony with Nature, not try to overpower her with brute force. As for weather warfare, the crucial question as I see it would be: Could the climate be modified surreptitiously so that the nation under attack would find itself in a very unfavorable weather trend without knowing the trend was being forced on it? I think the odds of that are vanishingly small.

Q—Why?

A—For the simple reason that, to modify climate on a large scale, especially on a selective geographical basis, you must do something highly visible—spread soot on the icecaps; install huge pumps in the Bering Sea and pump water one way or the other, or strew things over the sea surface to change its albedo. It's inconceivable to me that other nations would be unaware of what was happening and who was responsible for it. There is no way to modify climate on a large scale and keep it a secret from other nations—especially those with a half-way decent environmental monitoring program such as we have.

Q—We know that in the past there have been large-scale changes in climate, producing successive glacial advances. What might have caused those?

A—Let me answer that in the following way: The primary origin of climate changes on the scale of years, decades and centuries probably lies in interactions of the atmosphere with the oceans. The primary source of changes on the scale of 1,000, 10,000, or 100,000 years, however, comes from interactions involving not just the oceans but also the icecaps. The major ice sheets such as those that build up during the ice ages are never static; they are like a glacier on the flank of a mountain which is constantly being renewed at the top and melted away at the bottom. The ice is flowing through the glacier all the time. The same is true of an ice sheet during an ice age. The instant you cut off the source of moisture you start cutting down the size of the icecap. Anything you do to accelerate melting also cuts down the size of the icecap. Now I believe that, once an ice age begins, and the icecap builds up, forces gradually build up in the atmosphere-ocean system that will eventually break down that ice cap. So I think the ice ages are likely to be self-stimulating to a large extent.

Q—What's your opinion as to where we stand today? Are we heading toward another ice age?

A—It would seem that sometime within the next few thousand years we will be starting into another ice age. This would be just Nature taking her course. It's not that we have any theory to tell us this must happen. It's simply a matter of looking at the statistics of past ice-age events. These tell us the Earth has been unusually warm during the past 10,000 years—what we call an extreme interglacial period. If you look back through the geologic record, mainly through studies of deep-sea sediments, you find that the ice-age epoch which began about two million years ago has been characterized by alternating cold and warmth, with the extreme warmth like that of today lasting only about 10,000 years at a time. We don't know why; we can only point to this as a statistical fact. So the present warm period—already 10,000 years old—may be due to end fairly soon.

Q—How do you square a new ice age with your feeling that a man-made warming trend will be the important effect to look for in years ahead?

A—The warming trend would be a consequence of human activity; the cooling would be Nature doing her thing. It may very well be that human activities during the next few centuries *could* frustrate Nature's cycle, quite inadvertently.

Q—You mentioned that the ice ages began about two million years ago. What was the Earth like before that?

A—The prevailing state was one of rather benign tropical warmth, just the thing for dinosaurs. About 50 million years ago, that tropical warmth began to slip away, with a general, very slow cooling of the Earth. The cooling then proceeded to a point where about two million years ago the global climate quite suddenly "snapped" into an entirely different pattern characterized by waxing and waning of massive continental ice sheets. There were many, many cycles of this. We think each major glacial cycle took about 100,000 years to complete, so we're talking about something like 20 ice ages during the past two million years.

Q—What caused the basic change from continuous warmth 50 million years ago?

A—This is hypothetical, but I think the explanation has mainly to do with continental drift. Roughly 20 million years ago the circum-Antarctic ocean current was able to establish itself for the first time because South America and Australia apparently broke away from Antarctica about then. Antarctica drifted to the South Pole where it became thermally isolated and was left to develop a major ice cap. The Arctic Ocean came over to its position under the North Pole, which allowed a kind of thermal isolation there also, making it easier for glacial ice to form on adjacent land masses. All of these things presumably came about because of tectonic plate movement in the Earth's crust, what's more familiarly called continental drift. The growth of the Atlantic Ocean was very important. In the last million years, the ice sheets have always tended to develop around the Atlantic Ocean. There's something about the Atlantic that's very important to the ice ages.

Q—You mean the Atlantic Ocean is something relatively recent?

A—Yes. Not so long ago, geologically speaking, there was no Atlantic Ocean. Europe and North America were joined together, and so were Africa and South America.

Q—How long ago was that?

A—About 100 million years. That's all. Not so very long on the time scale of the age of the Earth, some four-and-a-half billion years. I share the view that continental drift set the stage for the ice ages that we've experienced for the past two million years—and will keep them coming along for a good many more million years unless man does something to break the cycle.

Q—Do you agree with the statement of NOAA climatologist James McQuigg that the past 15 years have been especially good ones in the U.S. from a crop-production standpoint, and that it stands to reason that this benevolent period is about to come to an end, based on climatological odds?

A—Yes. Jim McQuigg and his colleagues have convinced me that this is the case. We've been extraordinarily lucky because the weather in the major crop-growing areas of the U.S. has been uniformly good for many years—so unformly good that it's almost a fluke, in a climate that over the longer run has varied much more than that. To make plans as if the climate were going to continue so favorable to U.S. agriculture would be absolutely irresponsible.

Q—Which way would you plan? Wetter, drier, colder, hotter?

A—From the agricultural productivity point of view, the climate's not going to get better. It can only get worse. It could be more drought, or more premature autumn cold, weather-related problems in the spring, or any combination of those things. We've had a taste of it in the last year or two and we're going to get lots more. If there's anything we can be reasonably confident about in terms of projections of future climate, it is that the climate of our crop-growing areas will become more variable than it has been in the recent past.

NOAA In Miami

BY CARL A. POSEY

The paths of very different, still-evolving organizations converge in a fascinating way where NOAA meets Miami. But with all their diversity, there is something inevitable and fit about the way the dozen pieces, their 500 or so persons and their $24 million annual budget discovered one another.

They were brought together as all organizations are, by the successive strokes of managers' pens. But in Miami one is conscious also of more organic magnetisms and affinities at work. Curious men and women tied to the secrets of the global sea are natural neighbors for others concerned with the rich tropical life cupped in the warm waters of the Gulf and Caribbean. And it is just as natural that this reservoir of winter sun and summer house for hurricanes would attract those who seek to understand and change the atmosphere.

So that the elements of what is called NOAA-Miami converge here from paths which have brought them from the sea, its life, and its destructive atmospheric children.

The oceanic connection is most vivid out on Virginia Key, one of the boundary islands across Biscayne Bay from Miami, linked to the city by a four-lane causeway and a chain of roadside beaches. On this northernmost Florida key the palms, mangroves, and marsh grasses have been moved back to make way for one of the nation's major collections of ocean-focused people.

A striking concrete structure that looks a little like a castle and a little like a ship is the newest Virginia Key facility. Dedicated in early 1973, the building is home to the Atlantic Oceanographic and Meteorological Laboratories (part of NOAA's Environmental Research Laboratories), their hundred or so people, and programs which cover virtually the entire spectrum of the marine sciences. If the building is new, the functions housed there are not; much of the work done at the Virginia Key facility is today's end of a continuum reaching back into the research activities of the former Coast and Geodetic Survey. This is not to say there have not been crucial evolutionary changes.

"Five years ago," says Dr. Harris B. Stewart, Jr., director of the facility, "we were primarily deep ocean. But emphases change. We understood that our research would have to be more closely tied to immediate national problems, and so we turned more toward shore. We've become heavily involved in the New York Bight MESA project. We're participating significantly in the marine environmental assessment projects NOAA is managing for Interior's Bureau of Land Management. We're working to bring satellites and new remote-sensing techniques closer to the center of oceanography. We're linking continental drift, plate tectonic theory, and mineral-forming techniques along the mid-Atlantic Ridge. I think we may have a major role in describing the important oceanic inputs to short-term climatic fluctuations."

The Atlantic Oceanographic and Meteorological Laboratories are almost NOAA in microcosm. They comprise four smaller labs—for physical oceanography, marine geology and geophysics, sea-air interaction, and ocean remote sensing—and also provide a base for representatives from the National Ocean Survey's oceanographic instrumentation center and the Environmental Data Service's National Oceanographic Data Center, the port meteorologist of the National Weather Service, and people from the National Environmental Satellite Service. The NOAA-Miami library in the Virginia Key building is operated by the Environmental Data Service.

A very active place. But why do all this in Florida?

"Florida," Dr. Stewart says, "is like a finger poking down into the Atlantic and the Caribbean. On the continental United States you can't get any closer to the 'center of gravity' of the Atlantic. We're right *in* the coastal zone. We have, in the Florida Current, one of the world's major oceanographic phenomena right out our window. And we can work 24 months a year."

There are other compelling reasons, of course. One is the proximity of the other Virginia Key facilities. The University of Miami's Rosenstiel School of Marine and Atmospheric Science is across the boulevard, as is the Miami Seaquarium. Planet Ocean, a large oceanographic exhibit of the International Oceanographic Foundation, is being constructed less than a mile toward town. NOAA's Southeast Fisheries Center is a stone's throw away. Interactions are intensive.

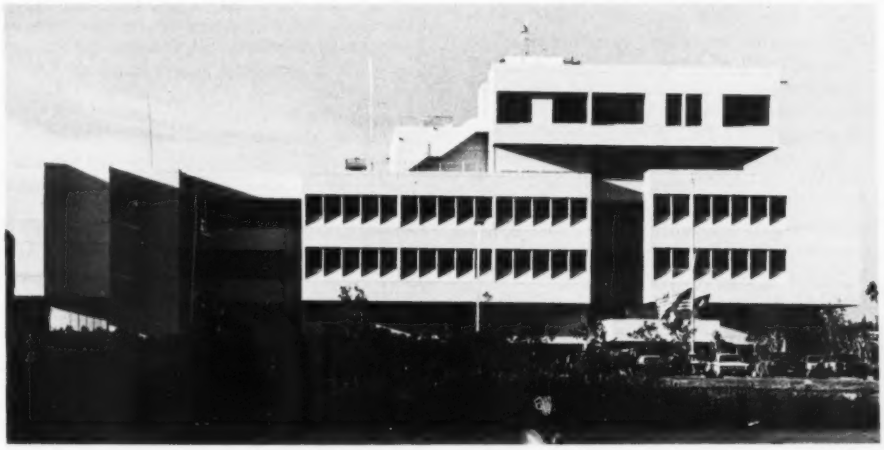
What is on Virginia Key today is seen as a kind of prologue, though. Dade County and the City of Miami have set aside much of the key for the clean industry of marine and atmospheric science. The university has one tract. Miami-Dade Community College has another for its budding marine technician program. Palisades Geophysical Institute, a private nonprofit laboratory, has five acres across the pond from the NOAA facility.

"Gradually," Stewart says, "a very nice marine science complex is developing out here. I'm sure that ten years from now this is going to be a large, bubbling, synergistic campus, which is exactly what we want. That's why this building looks inward, not out toward the road. We look for Virginia Key to become one of the leading marine and atmospheric research centers in the world."

Biscayne Bay, the sun-streaked band of blue water between Virginia Key and the Miami skyline, helps make such projections probable. It is a dominant element in any rendering of Miami. Since 16th century Spaniards put in behind the northern Keys for shelter from maritime storms—and ran the gauntlet of the Teguestas who lived at the mouth of the Miami River—Biscayne Bay has been a major theme in the life of the community and the life styles of its citizens. And this not-quite-lagoon, not-quite-estuary has come to be a major theme in the work of University of Miami Sea Grant activities, directed by Dr. Eugene H. Man. Miami's is one of only three private Sea Grant universities; the others are M.I.T. and the University of Southern California.

"Our emphasis on the Bay is guided by local problems," explains Thomas W. Bilhorn, associate director for programs of the Miami Sea Grant program. "South Florida has the unfortunate classification of being the fastest growing state in the nation. We just beat out California. Faced with this tremendous growth, we're trying to see whether the values which draw people here can be preserved, and, if not, what kinds of impacts different uses will produce. These are darn easy questions to ask, and darn hard ones to answer."

The Sea Grant effort has been working closely with metropolitan Dade County, which will be providing matching support. Bilhorn and his staff are concerned mainly with Bay ecology, and how we humans relate to that ecosystem. They are looking at circulation, bottom organisms, bay biota,



Dr. Harris B. Stewart, Jr., director of NOAA's Environmental Research Laboratories' Atlantic Oceanographic and Meteorological Laboratories in Miami, Florida, holds the plans of the facility's building, dedicated in 1973. The laboratory (above) is located south of Miami on Virginia Key.

Top left, research assistant Shirley Pomponi works on charts for Sea Grant's Biscayne Bay report; left center, Mel Brassfield sorts fish eggs and larvae; bottom left, Barbara Palko is growing phytoplankton cultures; top right, Thomas W. Bilhorn and illustrator Susan Suarez with Biscayne Bay report maps; above, the Southeast Fisheries Center Miami Laboratory.

critical nutrients, nitrogen cycles, turbidity, and the myriad ways in which the Bay is used as a resource. The problems are legion; the uncertainties, extreme.

"Take the problem of fish mortality," Bilhorn says. "We're trying to get a fish pathology program going here because we have fish kills and we don't know why. What percentage of the fish are affected? We can't reasonably sample the population, and tumors and other diseases have a variety of causes. We need to know whether it's something put in by man, or nature . . . or what? For all we know the fish may just be the tip of the iceberg, the first signal that a very serious problem exists. People ask us if the fish are safe to eat. We can't even answer that."

Nevertheless, Biscayne Bay's portrait, in the form of a comprehensive report, is nearing completion in the Marine Advisory Service rooms at the Rosenstiel School. There, the Bay is taken as a geographical area, and the question posed: how can this area be inhabited, optimally? The report is planned as a descriptive background for more informed decisions; there are no villains in the piece.

Because the NOAA Marine Advisory Service developed out of traditionally close contacts with fishermen and others who use the sea to make a living, one is a little surprised to find so little fisheries-related activity in the University of Miami program. The answer is a simple one, however. The University of Florida Sea Grant program fills the traditional extension service niche. And there is a fisheries powerhouse across the road from the Rosenstiel School—the Southeast Fisheries Center, a major focus for research in NOAA's National Marine Fisheries Service.

What is now the Southeast Fisheries Center began back in the 1950's, spearheaded, incidentally, by Dr. Thomas Austin, present director of NOAA's Environmental Data Service. When the Virginia Key facility opened in 1965, it was called the Tropical Atlantic Biological Laboratory, and its very existence meant that a persistent fisheries myth had begun to unravel—the Gulf of Mexico was *not* a sterile pond to be fished for nothing but shrimp, but held, in fact, some of the richest fishing grounds in the world.

Today, the Virginia Key laboratory is the hub of a much wider activity. It runs two other laboratories, the exploratory fishing activity in Pascagoula, Mississippi, which opened in 1950 with Stewart Springer as base chief, and a fisheries technology and remote sensing operation at Bay St. Louis. Two NOAA ships are assigned to the Center, the OREGON II, out of Pascagoula, and the GEORGE M. BOWERS, based in Miami.

The Center's is a unique beat among fisheries. The Gulf and Caribbean hold the only expanding fishing operations in the United States, accounting for some 40 percent of the total annual domestic catch (up from 10 percent in the 1950's). The region of interest—the Gulf of Mexico, Caribbean Sea, and the Atlantic up to Cape Hatteras, where marine life takes a yankee turn—is populated with something like a thousand species available in commercially interesting quantities, and marked by an international flavor that can be quite intense.

"From Brazil to the United States there are something like 13 continental nations bordering on this ecosystem," explains Center director Harvey Bullis. "Throughout the greater and lesser Antilles and the Bahamas and Caribbean there are problably another 20 political entities, most of which fish the same species off their own national coastline. It makes for an entirely different kind of fisheries management situation.

"For example, much of the fisheries activity down here has been developed with U.S. capital by U.S. fishermen. So U.S. Interests are involved when our exploratory voyages find shrimp off South America, spiny lobsters off Panama, deep-water snapper in the Caribbean. There are probably better than a thousand U.S.-owned and operated fishing vessels in the shrimp fisheries alone. We have to help sort out where the national interest lies."

Among the resource investigation efforts now under way at the Center (by way of Pascagoula) is a study of ground, the bottom-swimmers that can be taken with a bottom trawl. Croaker is the species of most interest here, because there is a large potential Japanese market which scientists at the Miami Center hope to open to American fishermen. (What is croaker like? A nice white meat; something like what you get in a fast-food fish sandwich.) Groundfish are also captured during normal shrimping operations, at a rate of six to ten pounds of fish for every pound of shrimp. A better croaker market might persuade the shrimpers to bring these fish in to the dock. On the other hand, a groundfish-centered cat-and-dog-food industry has interests that must be considered too.

So the Southeast Fisheries Center, besides looking for new resources, is trying to help develop resources that are not heavily

used now, and to stimulate new markets for species turned up in these surveys.

It is also, by way of the Bay St. Louis operation, trying to improve the ways in which these living resources are detected, pursued, captured, and statistically expressed. There has been a veritable flood of techniques from the Mississippi facility. RUFAS (for Remote Underwater Fisheries Automatic Survey) is a sled-mounted camera controllable from shipboard which can be towed at varying depths, photographing the seafloor and benthic life in living 35-millimeter color. A follow-on RUFAS II will be able to go down to 400 fathoms and has a terrain-following system built into its electronics. Another Dick Tracy type device is a directional underwater television camera that can be dropped over the side to videotape whatever's down there. And the Bay St. Louis people are working on new fishing gear for conservation purposes, and remote sensing devices like new sonars, low-light-level sensors, and lasers.

But one of their best products may be a computer-summary of offshore fishing resources—printouts that show not just where fish are but the amount of effort required to catch which species, a key to abundance. This is valuable to fishermen; it also offers help for managers trying to evaluate the environmental impact of proposed offshore structures.

The Virginia Key fisheries effort goes back to the 1950's, when the *Saturday Evening Post* was still a weekly and Philip Wylie still produced Florida-set serials about Crunch and Des and their charter boat, Poseidon. Those were the days when a mounted sailfish was either in a seafood restaurant or a millionaire's rumpus room, and Florida was where you went to catch one. Now the game is different, a fact which complicates the already complicated world of fisheries management.

"Miami, Miami Beach . . . they've always been famous as a place to visit on your vacation and go out for a billfish or sailfish in a charter boat," Bullis says. "But in the last fifteen to twenty years there's been a fantastic change in this. We have close to half a million registered boats capable of fishing off Florida coasts now, and this has brought a tremendous amount of fishing pressure to bear on these species. It's no longer a rich man's game."

The Center's effort here is to assess the population of the big, slow-growing game fish, to see what these pressures are doing to populations, and what management action is appropriate.

The complexities of fisheries research and management and of most other aspects of the sea mean that, sooner or later, Virginia Key scientists must take their ideas into the larger laboratory of the ocean. For many of them, offices ashore are just a place to work up plans for what they will do in their real place of employment—the deck of a research ship.

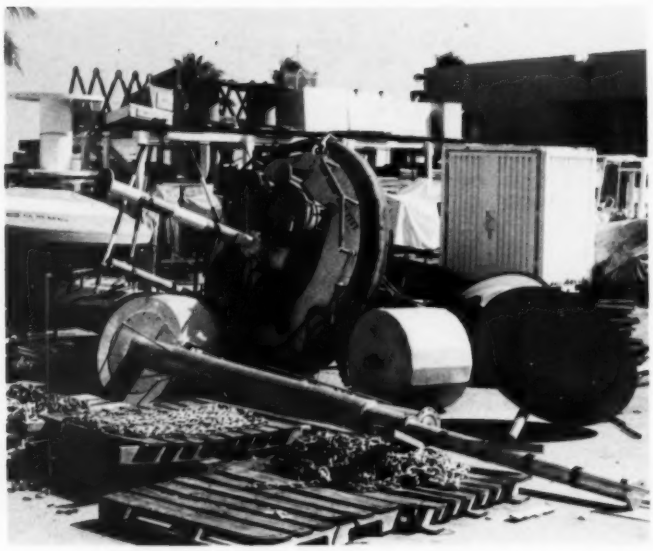
These platforms operate from another land form in Biscayne Bay—Dodge Island, a man-made 300-acre rectangle which was not there when the Spaniards came ashore four hundred years ago, or even when the first elements of what is now NOAA moved into the Miami area. Dodge Island was built—and continues to be built—for the new Port of Miami, which opened in 1964 and now handles about six million tons per year.

Above (from left), Joe Clark, Warren Keenan, and Blitz Krieg steady a GATE radar pedestal removed from the NOAA Ship Researcher at the Miami base; top right, Commander Robert Franklin, director of the Miami base, with the NOAA ships Researcher and Virginia Key; bottom right, aboard the Virginia Key, Tom Morrissey (left) and Burnham Neill work on winch gear.

NOAA's Southeast Marine Support Facility, a southern extension of the National Ocean Survey's Atlantic Marine Center in Norfolk, Virginia, occupies part of the south side of Dodge Island, and is home to some of the world's best-known research ships: NOAA's Discoverer, Researcher, George M. Bowers, and (when she's in town) Oregon II, along with the oceanographic laboratories' Virginia Key; and the University of Miami ships Gillis and Iselin. The Dodge Island facility also supports the Pascagoula base of Oregon II, and provides space and technical services for visiting research ships of all flags.

"The work here differs from other NOS bases," observes NOAA Commander Robert Franklin, who commands the ship facility, "in that the ships are not doing the traditional hydrographic survey work. These are mainly research ships, based here to support the laboratories over on Virginia Key. Of course we have field parties working through here on coastal surveys. But we don't run hydrography. The laboratories stage a lot of their projects out of here. For GATE, we had the Oceanographer, Researcher, Gillis, Iselin, and Coast Guard ship Dallas in here for outfitting."

The full name of NOAA's Dodge Island operation is the Miami Ship and Ocean Engineering Facility. The ocean engineering part of the title derives from the work of Commander Franklin's next-door neighbors, the Ocean Engineering Branch of the National Ocean Survey's Equipment Development Laboratory. Over there, welding torches seam steel spheres and tripods, metal-bound boxes carry the advisory: "RECORDING INSTRUMENT, HANDLE WITH GREATEST CARE," and there is



the racket of lathes and the other tools of the mechanical engineering trade. Out back is the boneyard, an old folks' home for buoy hulls and floats and weights and meters.

The product of this Miami facility has been a family of instruments designed to operate in the severe, equipment-digesting environment of the ocean. Most members of this instrument family had to be invented, and most of them exist nowhere else. These include the world's first deep-sea tide gage capable of taking data on the ocean floor for months at a time before being recalled to the surface by an acoustic signal. Buoy systems designed for use in Alaska's Cook Inlet also came from the Miami branch. These are tautwire, subsurface buoys, built for the kind of conditions Alaska calls to mind.

"I think some people expected us to go up and put buoy systems into Cook Inlet and watch the first good tide come down and wash them all out," says Charles Kearse, chief of the facility. "It's a harsh environment, with currents ranging up to five and a half knots. Very rocky bottom. A lot of silt in the water wears out current meter bearings in a hurry. But we've had a good success there."

Failures? Well, failures mostly stay in the ocean.

Charles Kearse (top left), director of the National Ocean Survey's Ocean Engineering Branch in Miami, Fla.; a swift-current buoy assembly takes form beneath the hand of draftsman Jorge Gonzales (bottom center); Michael Keller (top center) does some metal work for John Jennings and Donny R. Sharp (bottom left) who are preparing a bottom platform to receive the current meter being tested by Jack Falkenhof (top right); Engineer Bobby J. Taylor and John Jennings complete the current meter installation (left center). Bottom right shows the boneyard.

"Probably one of the greatest sources of satisfaction to us has been the adoption of a system concept to our equipment," Kearse says. "After what we put into a design there is just nothing worse than what we call failing at the rail. You invest a lot of money developing a system, get a ship, then try to put it over without any preliminary drill on deployment or retrieval, and it fails as it goes over the rail. Now we develop a package of procedures along with the equipment. The ship's just another element in the total system.

"The ocean is a very difficult environment for equipment. But we're using new materials and techniques, and I think we're winning. There isn't a lot of money, so you have to be clever."

In a way, this cleverness is changing the organization. The development part of the Miami unit is going back to Rockville, to be closer to the parent organization and the two sister branches already located there. The people who remain at Dodge Island will turn more to test and evaluation duties. Kearse feels it is an appropriate move.

"You develop a certain capability by being in this area, from exposures like ours to the Virginia Key labs. We've sort of grown to maturity down here. Now that our clientele represents all of NOAA, we have to get closer to large programs, and we can do that best by being with the other groups. This way, the design engineer working on the sensor aspects can work closely with the design engineer working on the ocean engineering aspect."

Across town from Dodge Island,the winds of change have been blowing for another NOAA-Miami dealer in platforms and sensors—airborne ones. Out at Miami International, in the Airtech Inc. hangar NOAA shares with maintenance-hungry jets, the groundwork has been laid for a new era of research aviation. The Research Flight Facility, run by the Environmental

Research Laboratories' Weather Modification Program Office in Boulder, has been renamed the Research Facilities Center and reconfigured into two smaller "firms," one dealing with aircraft operations and maintenance, the other with instrumentation systems.

Dr. James McFadden, who directs the aircraft operations half of the activity, notes that the change was inevitable, given the kind of aircraft NOAA will be operating in the near future. "The new aircraft," he says, "mean a quantum jump for us. Range, performance, data-collection—everything is going to go up sharply. It is an incredible resource, and we're reorganizing now to get ready to use this resource effectively. Among other things, we will be going more to the aircraft manager concept used by NASA on its 990. This puts a man with his airplane all the time, and puts him between the aircrew and the scientists. With the kind of equipment we're getting it's not a bad idea."

The "kind of equipment" refers to two Lockheed P-3 Orion aircraft purchased by NOAA. They are the first brand-new aircraft the organization has ever acquired—the tradition has been to use second-hand military aircraft—and the first opportunity the agency has had to incorporate special features while the aircraft is still on the assembly line. The first P-3 is scheduled for delivery next month. The second airplane will come in early next year. At about $10 million each, fully equipped, they are expected to be a mainstay of airborne environmental research well into the 1980's.

The airplane is only part of the new systems coming into the Miami facility. The instrumentation aboard the P-3's, developed by NOAA scientists in Boulder, may be the decade's most exciting technological development in research meteorology. This instrumentation is what will make NOAA's the best research aircraft in the world. And it has forced a change in the way instruments are regarded out at that Airtech hangar in Miami.

"In the past," explains Dr. Stig Rossby, who directs the instrumentation group, "instrumentation activities here were pretty much limited to technician maintenance. And the instruments were old, tube-type systems that had already been surplused by the military.

"Recent advances in various technologies permit us to acquire or develop some important and exciting new capabilities in airborne data management. These include new recording techniques, real-time computation and display systems, and in-situ and remote sensors which should give us much better access than we now have to information about the atmosphere. We expect to become a national center of excellence that can not only maintain but also develop and properly calibrate our new measurement capabilities."

But even as one anticipates the new airplanes and what they and their instrumentation system mean to researchers, Miami International makes one think of what must happen to the old. This is one of the world's great harbors for the tramp fleets which pop and wheeze down airways to the south, and the grass trapezoids between the concrete acres here abound with derelicts. Forty-Charlie, NOAA's old DC-6, is a big training aid over at a nearby airplane school, its life arrested in a purgatory of unending maintenance. And what a life it was! On the old fuselage flags of nations around the world recall the long flights for Equalant, the Indian Ocean Expedition, BOMEX; and rows of hurricane symbols evoke the hundreds of hours of flying one of the atmosphere's most violent phenomena.

For, old or new, these airplanes are the tangible symbols of NOAA's longstanding hurricane connection. The old DC-6's, the B-57, the C-130, the P-3's have been the means, the platforms, by which men and women have carried the scientific fight to the atmosphere—into hurricanes in the hope of learning to modify them, into the incipient storms called cumulus clouds to see what can be done with these basic weather factories of the atmosphere.

As spring makes its slight presence felt in southern Florida, preparations are under way at NOAA's laboratory on the Coral Gables Campus of the University of Miami for the first cumulus cloud-seeding experiment since 1973—FACE 75, it will be called, for Florida Area Cumulus Experiment, 1975. Work done thus far in cumulus cloud experimentation has brought the Miami investigators about a third of the way to being able to say their hypothesis works, or doesn't. The hypothesis is that seeding cumulus clouds promotes mergers of individual cloud systems, and that these clouds produce more rain than would be produced naturally by single unseeded clouds. Thus far, there is evidence that within a given cloud area, the technique increases rainfall. But it is not yet evident that rainfall has also increased over the entire 5,000-acre target area near Lake Okeechobee.

Top left, Dr. Stig Rossby, Director of NOAA's instrumentation facility at Miami International Airport, headquarters for Research Flight Facility, inspects sensor on plane; to right, Dr. James McFadden, Director of the aviation activities of the RFC, chats about operations; above, the first of two new Lockheed WP3D aircraft NOAA is acquiring for a variety of scientific efforts, is shown after rollout last November at Lockheed's Burbank, California facility. The two new craft will incorporate most modern instrumentation, are extremely versatile.

Top left, Dr. William L. Woodley, who directs the Coral Gables-based cumulus cloud seeding experiment; top center, John Cunning measures water drop size distribution on impact record from airborne instruments; top right, Joyce O. Donaldson measures cloud radar-echoes using a planimeter; bottom left, Jack L. Thomas checks radiosonde circuits; bottom center, Victor Wiggert studies computer results from a program used to isolate and track rain showers recorded on the laboratory's digitized radar; bottom right, James Dugranrut troubleshoots a densitometer.

"We'll know better after FACE 75," says Dr. William Woodley, who directs the cumulus experiment. "We've incorporated what the experiments of 1971 and 1973 taught us, and we know how we should be measuring convective rainfall. Our problem is the familiar one of trying to pick the real signal of what man is doing out of a greatly varying natural background. Initially we thought that 100 total days of experimentation would give us an idea whether this worked. Thus far we have 37 such days."

A major difference in this year's effort will be the use of satellite data to study the large-scale effects of seeding. This should point up, for example, whether seeding increases rainfall over an area, or produces more rainfall from one cloud while suppressing rainfall somewhere else in the environment.

One of the major results of the cumulus program thus far has been to support fundamental changes in the hypothesis behind Project Stormfury, a cooperative effort with the military and others to determine whether hurricanes can be modified beneficially. This recognizes what a recent consolidation of the cumulus and hurricane research efforts did—that cumuli and hurricanes occupy different ends of the single scale of tropical meteorology. Thus, the new National Hurricane and Experimental Meteorology Laboratory combines the expertise of both efforts, and permits the use of a team concept in accomplishing the two missions.

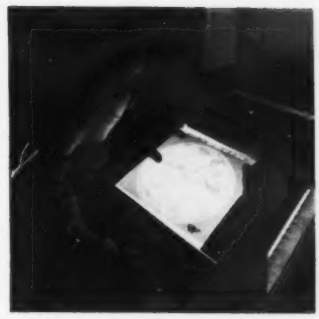
Stormfury has been down for two years now and is not expected to begin again until the summer of 1977, when it will be based in the Pacific, where experimental opportunities are several times what they are in the Atlantic. But the down-time has not been idle. In general, the scientists find themselves better prepared for the experiment than they were several years ago. Dr. Cecil Gentry, recently retired director of NOAA's hurricane research effort, explains why.

"We have only had our cloud physics instrumentation on the aircraft since 1973, so that we've only had a good idea of a hurricane's water content since then. The original Stormfury hypothesis was that seeding supercooled water in the eyewall caused the water to freeze, releasing heat into the eyewall and causing the eye to expand and the storm to lessen in intensity.

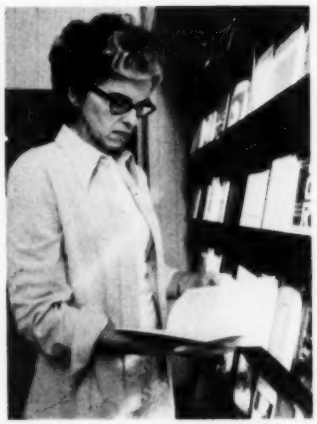
"We know now that there is not enough water in the eyewall to release that kind of heat. So we have moved out of the eyewall to other clouds, and are applying the techniques developed in the cumulus experiment to create a new eyewall, outside the original one. This would change the storm's wind and pressure fields.

"It has always been easy to seed a storm. It's easy to tell if it changes. Now we are better able to see whether we produced the observed change. We are much farther along on being able to reason from cause to effect in the hurricane."

Beyond planning the Stormfury modification work, investigators at the Miami facility



Clockwise from top left: Dr. Neil Frank, National Hurricane Center director, leads map discussion. (From left) Dr. Frank, Miles B. Lawrence, Mildred A. Kirkland, Joseph M. Pelissier, John R. Hope, John J. Drost, and David L. Cohen (NESS); Mildred A. Kirkland mounts magnetic tape; Francis J. Drybala broadcasts high-seas weather information; Ivis Edell Pinter, of Management and Technical Services Company, gridding satellite negatives; John J. Drost operating cathode-ray tube display of weather data; Herbert H. Hill takes an observation in National Hurricane Center's radar room; Raymond E. Biedinger and William Stosser prepare forecasts; (left) Alvin M. Samet prepares NOAA Weather Radio tape; (right) Howard A. Friedman in the Tropical Meteorology Center analyzes weather chart; Henry F. Silsby briefs an international flight.



Top left, student draftsman Julio Diaz; top center, the AOML computer center; top right, librarian Claire Jergens; left center, Jerry Hood operating laboratories' single-sideband station; center, Don Waters, a Sea-Air Interaction Laboratory physicist, plays data back through oscilloscope; right center, Robert Berles works on an airborne laser used to profile wave heights; bottom left, Donna Rona examines acoustic records of internal waves; above left, Bill Sawyer cuts a sample from a frozen core, while Douglas Lambert (above right) X-rays another; Karen Ramryz packages MESA samples.

have been working to improve predictive models used by hurricane and storm-surge forecasters. When these and other models mature, the transfer to the operational forecasters of NOAA's National Weather Service should be swift—the National Hurricane Center occupies the top floor of the same University of Miami building which houses the hurricane and cumulus researchers.

This Weather Service office straddles two worlds. One is the relatively benign one of Florida weather (benign unless your orchards are under a frost warning, or your parched fields have incandesced, or your flight plan has carried you into one of those indigo-green Florida thunderstorms, or a tornado has dropped into your neighborhood) in particular and tropical meteorology in general; the other is the violent world of the hurricane.

The day-to-day weather job in Florida is a big one. There is a major agricultural-weather requirement to support the state's hundreds of truck gardeners, orchard growers, and ranchers. There are hundreds of thousands of sea-going craft, all quite weather-sensitive, and thousands of aircraft operations, including the international flights for which Miami makes such an excellent jumping-off place. The Coral Gables office is also one of the World Meteorological Organization-designated Tropical Meteorology Centers, providing analyses of meteorological events from Africa to the eastern North Pacific.

Still, Floridians know they live in hurricane country. It is as though they understand that Florida weather is Florida weather, with hurricane as the meteorological king. Or queen. This duality has split the office in untypical ways.

"For the state job," explains Dr. Neil Frank, director of the facility, "we have the same role as the lead forecast office in every other State of the Union. We're the Weather Service Forecast Office for the State of Florida. We have ten other stations under us in the State, to which we give guidance and whose products we monitor. These include a Weather Service station out at Miami International, which provides a direct contact for the extremely busy aviation community there. We also have forecast responsibility for aviation and marine interests over a large portion of the Gulf, Caribbean, and Atlantic.

"Because we have this other duty, my

Top left, Adriana Cantillo prepares MESA sediments; top center, Franci Nastan reads rapid sediment-analyzer; top right, Pam Bates looks over data from the mass spectrophotometer; left center, George Berberian and Maxine Weiselberg operate water sample auto-analyzer; center, NOAA Lt. (j.g.) Richard West looks at X-ray diffraction record; bottom right, Robert Roddy works on an acoustic release device; bottom left, Miami Field Finance Officer Kathryn M. Toney; above left, Dr. George Maul traces currents in satellite photographs; above right, Ben Culverhouse with shallow-water bottom tide gage.

deputy, Bob Cole, is meteorologist-in-charge of the Miami Weather Service Forecast Office. This arrangement leaves me free to concentrate on the hurricane warning service."

Hurricanes have given the facility its own flavor. There are video readouts in the communications room, early harbingers, one supposes, of AFOS, the Weather Service's automated real-time data system. A field office from the National Environmental Satellite Service sees that data from NOAA, DMSP, and the geostationary spacecraft flow into the weather system here—particularly into the hurricane warning system. The Center is also plugged into the big computers at the National Meteorological Center in Maryland, to pit models against the destructive reality of the hurricane. An Air Force office here coordinates military hurricane reconnaissance flights with the hurricane forecasters' special requirements. Not your run-of-the-mill weather station.

The focus of this activity during hurricane season is a "hurricane central," a specially designed room with readouts and consoles and other features that lighten the forecasters' load. The meteorologists who serve in the hurricane room are specialists, charged with research in winter, and hurricane forecasting and warning in summer. Their reach is considerable. From Coral Gables, they provide the central hurricane warning apparatus for the entire Atlantic and Gulf coasts of the United States, and for the abundant foreign coastlines of the Caribbean and Central and South America. Hurricane warning offices in New Orleans, Washington, DC, and San Juan, Puerto Rico, take up the regional hurricane burden when a storm enters their sectors. But the principal detection, warning, and forecasting problem rests with the National Hurricane Center.

Still, forecasting and warning is only part of the battle. There remain crucial questions of how well the hurricane hazard is understood here, and how well the warnings will be applied next time a major hurricane sweeps the Peninsula.

"Right now," Frank says, "we're in a period of comparative inactivity here in Florida. Our last intense period was the 1940's. In that decade we had nine moderate to severe hurricanes in the state of Florida. Historically, southern Florida gets more severe hurricanes than anywhere else in the United States. I think it's only a matter of

Fisheries Research Important in International Negotiations

Scientific data are vital to U. S. negotiators in seeking and reaching agreements with representatives of foreign nations when they consider who owns a certain living marine resource, and how it should be managed. NMFS Fisheries Centers provide such information to U. S. negotiators.

One example took place last November when scientists from the Southeast Fisheries Center, accompanied by a National Park Service biologist, boarded the NOAA ship George M. Bowers to study the spiny lobster in waters around the Dry Tortugas. The creatures which provide the seafood delicacy most of us know as "lobster tails" were collected, tagged, and released at another location. As they moved through the water, they were studied and measured, and details sent to Washington.

The George M. Bowers, at top left, is shown at Fort Jackson National Monument in the Dry Tortugas. Top right, divers prepare for the spiny lobster experiment as NOAA's Chester Buchanan, above, sets camera before handing it overboard for underwater photographs which are often extremely valuable during negotiations with other nations in discussions that can lead to conservation measures which may help save a living marine resource from depletion. At right, Gary Davis of Interior's National Park Service holds up a typical sample of a spiny lobster.

time before the activity swings back up, and when that happens I just don't know how people will react.

"The problem is mainly a lack of experience. A lot of people think they've been through a hurricane when they get touched by the fringe winds and heavy rains. And I wouldn't say they hadn't. But getting a direct hit from a Camille-type storm is something else. We estimate that about 70 percent of the people down here have no experience with hurricanes.

"I think that right now we're at a point where improvements in our technology are not going to come very fast. We're on a plateau and to get off that plateau is going to take an awful lot of time and effort. We expect to have steady improvement in our forecasts, but no dramatic breakthrough. Given that, how are we going to protect these people who have no hurricane experience? I think we have to go back to public information."

As "Dr. Hurricane," Frank is a notable practitioner of what he preaches—and what he fears for the community. A drive to Key West evokes, for Frank, the problems of evacuating the lowlying keys in the path of a large hurricane. High-rise office buildings represent one of his hopes for an emergency alternative to horizontal evacuation of the low-lying city: properly anchored to deep pilings, the buildings might ride out a serious storm, and provide shelter in their hallways.

"We've got a moral obligation," notes Frank, "to help the guy who's coming down from the north and all he's got is a little bit of saving. He should know that in certain areas a hurricane could wipe him out. If he has that information, he might move to higher ground—or he might go on and live in a vulnerable area. I just want him to know what his vulnerability to hurricanes is.

Scratch a metropolitan area of a million or so souls and you'll turn up problems. Dade County is no exception. Hurricanes and little hurricane experience, pressure building on the marine environment and coastal lands, problems of handling wastes, finding water, and preserving the qualities for which people renounce New York, Chicago, and Detroit—these are difficult equations to solve. But the governments which work together to run Dade County have a reputation for problem-solving, and, in organizations like NOAA-Miami, they have more than the usual cut of problem-solvers. In fact, there has already been considerable local emphasis on the work of NOAA groups here. In 1971, the cumulus cloud experiment started early, in the hope of easing the drought with the experimental tool of cloud seeding. The Virginia Key labs have helped the local government look at what happens after wastes leave area sewage outfalls and how these outfalls influence certain types of fish and shell-fish. They've helped resolve matters of powerplant siting, and they're working with the state to produce the nation's first thorough survey of the resource-rich boundary between Florida and the sea.

NOAA Profile

With 1000 species to think about, Mary Thompson is a

Woman in Motion

She's come a long way from the girl chemist who began a fisheries career in 1957 at Pascagoula, Mississippi. In fact, Mrs. Mary Hamm Thompson has moved into the mainstream of some of the world's most complicated resource management problems—and into the deputy director's chair at the Southeast Fisheries Center, where many of these problems must eventually be solved.

In her sunny office at the Virginia Key facility, Mrs. Thompson radiates interest and energy, even in repose. In motion—for example, when she is chalktalking a visitor through the southeast fisheries operations—she is quick as a flyweight, and tends to blur. But if her size and weight remind one that women were once called "frails," her preoccupations do not.

She faces, with the labs under the Southeast Fisheries Center's jurisdiction, the extremely difficult problems of sorting out the separate interests of several dozen political entities around the Caribbean and Gulf, to find consensus about which fish are taken where, and how, and when.

In the dazzling blue waters outside her window, scattered from Cape Hatteras down to the northern hump of South America, a thousand or so species live in commercially interesting quantities. She ponders how they may be made useful to humans, to fishermen; and how new tools can be forged with which to find and fish them.

"We have several unique problems down here," she says in a midwestern voice greatly modulated by twenty years along the Gulf. "One is that the species tend to be shortlived. They have a lifespan of maybe three to five years, whereas cod or that kind of northern fish might be of marketable size when it's eight or nine years old. So they grow fast in these warmer waters. Some of them, like shrimp, are what we call a one-year crop. Same with the calico scallop, which only lives about a year. Some northern scallops aren't harvested until they're ten years old."

There is something friendly and vernacular in the litany of southern fish names: croaker, bluefin, grouper, stone crab, snapper. Fisheries people are no more sentimental about the creatures they study than fish are about fish. "I tend to view fish as a resource," Mrs. Thompson says, "but I also see them from a chemical viewpoint. My specialty before coming over here was biochemistry of a number of invertebrates and vertebrates. You can have invertebrates of the shrimp-crab type and they'll do one thing for you chemically. Then you take the clams and oysters and they'll do another. I was more interested in invertebrates, especially shrimp, because when I first started working on composition and biochemistry

Ms. Mary Thompson, Deputy Director of the National Marine Fisheries Service's Southeast Fisheries Center in Miami, is concerned with some of the world's most complex fisheries management problems. Her work has gained international acclaim.

we were attempting to isolate their protein components into weighable groups. It turned out that shrimp are nowhere near what fish are, biochemically. For example, shrimp have very little collagen, which is connecting tissue, and what they do have contains tryptophan. . . ."

Well . . . okay. The tryptophan discovery resulted in several papers and a good deal of comment for Mrs. Thompson and her companions in biochemistry. The honors keep coming: she was last year's winner of the Atlantic Fisheries Technological Conference award for superior achievement in technology.

"Until 1971," she says, "I worked for the old Division of Technology in fisheries. I'm a chemist by trade. I moved down here just before formation of the center, to work on pollution problems. Then they reorganized fisheries and Harvey Bullis came down. I don't know exactly how I got selected for this job. Maybe for planning detail. . . ."

Asked how a midwesterner settled for the south, Mrs. Thompson says, "It's odd. I've run into a lot of people from the midwest down here. I think if you like water and you get exposed to the ocean, you don't want to leave it."

As Mary Hamm (she insists there is no land of sky-blue waters connection), she attended Albion College in Michigan, and later worked about three years as a medical technician at Duke University Hospital Research Center. "We were working mainly on blue babies, cardiovascular involvement, open heart surgery, stopping the heart . . . at a time when there hadn't been much work of that type."

It took the south a while to "take" on Mary Thompson. She lived in the south for a time, when her former husband went to Duke, then moved to Pascagoula. "I've been southern ever since, mostly along the Gulf."

Coral Gables is an area stronghold of NOAA people. Mrs. Thompson lives there with her mother, who came down last summer, and one of her sons, Jeffrey, who is twenty and working. Another son, Richard, is 22, married, and living in Albuquerque for the mountains. Also in the house are a Siamese cat and a Britanny spaniel.

"I sew, I like to do embroidery and knit and that kind of thing. I do a lot of crewel work. Play bridge. Read a lot. I used to own a boat, but I sold it because it was kind of an awkward size for the area. Now I go fishing with friends. And I spend a lot of time in my pool."

What about her role as a professional woman?

"I'm not a libber," she says. "I feel that women should be paid what a man would get in the same job. But I don't feel discriminated against. And I think the Civil Service has become extremely aware of this kind of discrimination, so that there is less and less of it around government."

She is not one of her big preoccupations. Her attention moves quickly back to those thousand species, what they mean, and to the future.

"This is the only tropical coast in the United States," she muses, "and not many people have studied what environmental changes do to tropical fish. Can they tolerate as much as northern species, or not? We're being asked to help other agencies with some biological work of this type. We're writing proposals for assessment and monitoring of the sewage outfalls from Dade, Broward, and Palm Beach counties to determine their effect on marine species. We want to see how well—and whether—an area recovers biologically from having had an outfall, and what impact new outfalls farther out will mean. I think we'll be doing more and more environmental work. We don't even have answers to some basic questions, like are we dealing with a more or less fragile ecosystem down here than up north? I don't think anybody really knows."

Mary Thompson is going to help fix that.

Delaware Sea Grant looks to the

Shellfish Factory Of the Future

BY ANN K. COOK

Memories of the past; vision of the future. . . .

Both pervade a modest cinderblock building in shorelands near Lewes, at the mouth of Delaware Bay.

Originally, it was a menhaden-processing plant, producing fishmeal for Delaware's poultry industry. Then the menhaden left for other waters.

The structure was converted to an oyster-cleaning plant, where impurities were removed from the shellfish that abounded in the Bay. The oysters, too, are nearly gone now.

Today, the building houses a unique facility that is an important part of NOAA's aquaculture program. It is the only facility in the nation raising oysters and clams from egg to market size in a closed, recirculating seawater system. Here a Sea Grant team from the University of Delaware's College of Marine Studies is growing "supershellfish" in an environment totally free of the vagaries of nature.

At the end of February 1975, their initial clam crop reached the market size of a small cherrystone clam—the first time this has ever been accomplished in a closed-cycle seawater system. Closed-cycle aquaculture systems continuously circulate and purify the water in them, rather than taking it in from nearby water sources and returning it after use. Most of them have been fresh water systems, used for fresh water marine organisms.

From spawning to adulthood, this first crop of aquacultured clams grew in a little over two years, compared to the three-to-five-year normal growth period of oysters and clams in their natural environment. As techniques have been improved and refined, the project's subsequent oyster and clam crops are growing even faster.

Dr. Kent S. Price, Jr., an originator of the project who is now Associate Dean of the College of Marine Studies and Director of its Marine Advisory Services, says that closed-cycle aquaculture, with selective breeding and proper diet "has the potential for producing prime, disease-free oysters and clams." He adds: "We hope to develop a commercially feasible system capable of growing—at a cost of 30 to 50 dollars per bushel—uniformly shaped, attractive, gourmet-quality shellfish—a product that restaurants are already buying at very high prices.

A former menhaden-processing plant near the mouth of Delaware Bay houses the nation's only facility raising oysters and clams in a recirculating seawater system. (Opposite page) Operated by the Sea Grant program of the University of Delaware's College of Marine Studies, the aquaculture laboratory is surrounded by a commercial fishery business.

"Similar techniques could be used for raising other mollusks, as well as finfish and crustaceans. They could be grown far inland, using transported or reconstituted seawater."

According to Dr. Price, Delaware Bay's prolific oyster beds produced some nine million pounds of oyster meats in 1950.

By 1970 the annual harvest gathered by Delaware and New Jersey oystermen had fallen below one million pounds.

"Several nearly simultaneous occurrences essentially wiped out the Delaware Bay oyster industry," Dr. Price believes.

"As industrial and residential development increased, the Bay's watershed was deforested and more water ran off the land into the Bay, bringing with it greater loads of silt. Silt is the enemy of the oyster; unless it grows faster than silt accumulates, it will be buried and die.

"At the same time," he says, "the oyster beds were being mismanaged. Oystermen did not replenish them with shells. Without shells to attach themselves to, young oysters cannot begin to grow."

"A third factor," Dr. Price continues, "was the introduction of pesticides, especially to control salt marsh mosquitoes. For mosquito control, pesticides are sprayed in the warmer months, just when oysters are in the larval stage. Entering the water, the mosquito-destroying pesticides also destroy the oyster larvae."

Delaware Bay, forming a watery wedge between New Jersey and Delaware, provided more than a once-thriving shellfish industry for the two states. A natural superhighway for marine transportation, it has become the nation's second largest oil port. The increasing oil in the Bay's waters was still another reason for the drastic decline of the oyster population.

The final blow was an epidemic of a disease with the scientific name of *Minchinia nelsoni*—called MSX, for short—which caused a catastrophic collapse of the Bay's oyster industry in the late 1950's and early 1960's.

With support from the National Marine Fisheries Service—then the Bureau of Commercial Fisheries—Delaware and New Jersey began trying to reestablish the Bay's oyster industry, principally by means of a large shell-planting program. University of Delaware biologists began studying oyster mortality, seeking a disease-resistant strain to use in repopulating the Bay's oyster beds.

In 1966, Dr. Price and his colleague, Dr. Donald Maurer, carried the effort a step further, initiating a project to collect survivors of the epidemic and develop a disease-resistant strain that could be hatchery raised and then moved to the Bay's oyster beds. "Based on previous mortality studies and using advanced aquaculture techniques," Dr. Price recalls, "we set out to produce a

Photographs by the University of Delaware College of Marine Studies.

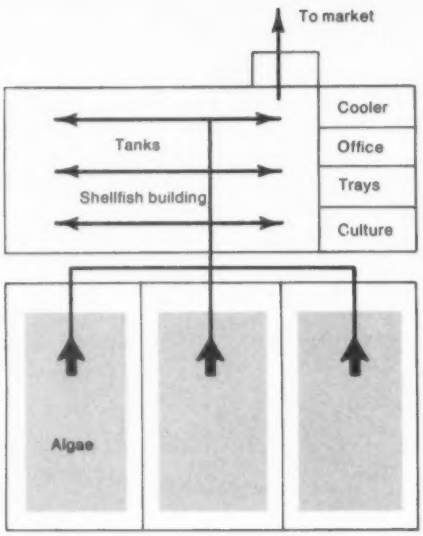
disease-resistant oyster that also demonstrated fast growth and good market qualities. Our procedure was to spawn resistant stocks artificially in the laboratory, rear and set the larvae under hatchery conditions, and test the progeny, under field and laboratory conditions, for the desired disease and market characteristics. First, we had to develop the necessary techniques for holding and conditioning Delaware Bay brood stock for controlled spawning; to spawn these oysters on demand; to successfully rear and set larvae; and to place young oysters in the field for convenient and safe monitoring and retrieval. In 1967, we achieved a significant breakthrough in conditioning and spawning Delaware Bay oysters out of season."

In the same year, new developments combined to bring about an expansion of the shellfish research program. Price and Maurer had become convinced that the problems of the oyster industry in Delaware Bay could not be solved by biologists alone. Also, the University was seeking a multidisciplinary marine project suitable for submission to the newly created National Sea Grant Program. The Delaware Bay oyster problem was a regional one; it required a task force or multidisciplinary approach; and it was consistent with the guidelines of the National Sea Grant Program. Although additional disciplines were brought in when Sea Grant funded the project in 1968, its goal was still to develop oysters for repopulating the Bay.

After two years' more work, the Delaware Sea Grant scientists concluded that—because of the Bay's degradation by silt, oil, and pesticides—repopulation was not the best solution. They decided to venture into new and unexplored scientific territory. They would continue to select and hold brood stock, spawn them, and rear and set the larvae. But then, rather than place juvenile oysters in the Bay to grow to adulthood, they would raise the oysters to market size in the laboratory. To do this, they would have to develop a continually recirculating, environmentally controlled, seawater system, in which oysters and clams would be fed diets of cultivated algae or artificially prepared foods.

Raising shellfish in such a system has many advantages. The crop is totally isolated from the natural and manmade disturbances that can destroy an industry virtually overnight. It grows faster because it grows year-round. Toxic metals and other pollutants present in natural waters and stored by shellfish can be eliminated from the water in the closed-cycle system. Shellfish produced in a controlled environment are uniform in size and shape, a great marketing plus. Furthermore, closed systems can be operated almost anywhere, eliminating competition with recreational and other interests for the use of bays and estuaries.

"The ultimate value of closed-cycle aquaculture may lie in the future," Dr. Maurer believes. "If our environment should become hopelessly polluted, we could still



The Delaware Sea Grant scientists' vision of a commercial closed-cycle aquaculture system has separate buildings for shellfish growing tanks and for raising algae.

produce shellfish and other marine foods commercially in the artificial growing systems."

So the University of Delaware Sea Grant researchers launched an unprecedented project with a difficult goal: to produce fast-growing, palatable, nutritious oysters and clams, free of toxins and disease-causing bacteria, in a recycling, controlled environment seawater system, at a reasonable cost, unhampered by legal constraints, utilizing natural sources of energy, and recycling organic wastes. When development of the system has been completed, it will be available for commercial adaptation by industry.

Creating a system for raising shellfish from eggs to adults is comparable in complexity to the development of life-support systems for astronauts during long-lasting space flights. Good diets must be provided, wastes disposed of, and the sealed-off environment kept disease-free and healthful. But, unlike that for spacemen, the shellfish support system must foster the greatest possible rate of growth.

To solve the tangled web of biological, feeding, water quality, technological, marketing, legal, energy, and investment problems, the University assembled an interdisciplinary research team under Dr. Melbourne Carriker of the College of Marine Studies. This team now includes: biologist Dr. Charles Epifanio; engineers Gary Pruder, Richard Dick, and Frederick Costello; chemists Dr. Richard Srna, and Jonathan Sharp; visiting molecular biologist Dr. Ellis Bolton; microbiologists, Dr. Marenes Tripp, J. Noble-Harvey, Diane Herson, Rodney Gray, and Kevin Smith; and attorney Joseph Bockrath. Support for the effort is provided by the university, the state, and industry, as well as NOAA.

According to Dr. Price, the team first surveyed all of the avenues of research that might contribute to the effort, and then selected only those which must be carried out to make the system commercially feasible in the shortest possible time.

Fortunately for the Delaware Sea Grant team, hardshell clams and oysters are far less complex animals than man or, indeed, than many other marine creatures. They live and grow in very close quarters in nature, as they must in cultivation facilities. Their behavior to each other is relatively quiescent, in contrast to the aggressive, cannibalistic behavior of lobsters. Being herbivorous, rather than carnivorous, oysters and clams can be fed inexpensively on algae. Another shellfish attribute with vast potential advantages for the future is that their wastes can be recycled to provide nutrients for growing their own food.

Four years ago, the University leased land for a Mariculture Laboratory near the point where Delaware Bay meets the Atlantic, allowing the aquaculture team's research to be consolidated in one physical facility—the quarter-million-dollar building donated by the processing plants that once had served the menhaden and oyster industries.

In its two-story, 10,000-square-foot area are a seawater system; three controlled environment rooms for hatchery, brood stock, and algal culture; water quality and microbiology laboratories; other laboratory facilities; and general offices.

Seawater is pumped from 1000 feet out in the bay into two 125,000-gallon storage tanks where sediments are allowed to settle. Inside the building, water temperature is regulated by the air temperatures in the various laboratories.

The team's biologists, chemists, and engineers designed the facilities and the systems, with the aid of a computer analysis of all the variables in terms of cost savings.

After the first recirculating system had been constructed in the new laboratory, the scientists tested it by filling it with filtered Bay water and stocking it with locally caught fish. While the fish lived in the system, the quality of the water was monitored intensively, and the filtering technique was readied.

Then, in 1972, the fish were removed, and juvenile hardshell clams were placed in the system to begin their closely controlled growth to adulthood. Later, more clams—and oysters—were put in the growing tanks, which now hold 16 groups of shellfish.

"Each spring," says biologist Charles Epifanio, "wild clams and oysters are collected as brood stock for producing eggs and sperm. They are held on screen-bottomed racks in flowing seawater kept at a constant temperature of 59 degrees F (15 degrees Celsius). A measured diet of cultured algae is added to the water, but the brood shellfish also have access to natural nutrients present in the water. After five or six weeks of this conditioning, clams and oysters can be spawned at any season of the year. They can be held in a state of spawning-readiness for almost a year, but do eventually lose their ability to spawn on command.

"Spawning is triggered by transferring brood-stock shellfish rapidly to warmer, 82 degrees F. (28 degrees C.) water," Dr. Epifanio explains. "While this shock is often enough to induce release of sperm and eggs, some sperm is usually introduced into the water as an added stimulus. A single female produces 50-100 million eggs in one spawning, and in the laboratory 80 to 90 percent of the eggs survive. Eggs and sperm are collected, small amounts of sperm are added to the suspension of eggs and fertilization occurs. About 24 hours later, minute larval forms develop. Only four-thousandths of an inch (100 microns) in diameter, they already have two valves or shells and a swimming organ. The larvae are grown in hundred-gallon (400-liter), cone-shaped glass fiber tanks, and are fed on varying diets of cultured algae. Each of the six tanks can hold 12 million larvae. Larval development is completed in an average of 10 days for clams and 16 days for oysters. These hatchery techniques are ready for transfer to industry now.

"When they are about to undergo metamorphosis," Epifanio continues, "the larvae are inspected, and the faster-growing specimens are placed in growing tanks, where they are allowed to set on the sides and bottom. Metamorphosing clams attach themselves to underlying materials by means of fine threads or 'anchor lines,' while oysters normally cement themselves to previously deposited shells. The process of attachment is called 'setting,' and the material to which they attach themselves, 'cultch.' Clams eventually detach themselves from the bottom and sides, but with oysters the bottom and sides of the growing tanks must be covered with thin sheets of plastic so that the larvae will set on the plastic and not on the tank. After several weeks of growth, the oysters are scraped gently from the plastic, and the detached oysters are placed once again in the growing tank. This method, one of several for the production of cultchless oysters, was developed by the Virginia Institute of Marine Science. Young cultchless oysters develop into uniformly shaped, high-quality oysters, commanding the best price. Thus, the effort of producing them is justified."

In the original system developed by the Delaware Sea Grant team, 32 growing tanks are supported above a 4200-gallon (16,000-liter) pool, where the circulating water is purified. Twice a day, freshly filtered water is pumped into the growing tanks, after water from the tanks has been emptied into the filter area. At the bottom of the pool is the biological filter, a three-inch (7.6-cm.) layer of shell covered by a silicate gravel layer of the same depth. An ultraviolet treatment unit destroys all but .005 percent of any fecal bacteria in the water. Dissolved organic matter is controlled by an activated carbon filter; alkalinity by periodic additions of calcium carbonate; and salinity by additions of fresh water. Airlift pumps circulate the water through the filtering systems. Protein skimmers and biological monitoring systems are now being developed for incorporation into the facility.

The University's Sea Grant scientists now have successfully completed and operated a second-generation prototype closed-cycle seawater aquaculture system, in which five bushels of shellfish can be grown.

(Top) As many as 10 trillion algae cells per day are grown in culture vessels to feed the hungry shellfish. (Above) In the algae culture room, graduate student Robert Frank calibrates the fluorescent light essential to algal growth. (Right) Project microbiologist Kevin Smith measures seawater temperature in the new microbiology laboratory. The team's microbiologists also monitor the shellfish and the seawater in the closed-cycle system for bacteria and viruses.

A third-generation, 50-bushel prototype, incorporating features that enhance the commercial feasibility of this kind of aquaculture, has been designed by Dr. William Gaither, Dean of the College of Marine Studies, and is expected to be ready for operation by 1976.

Clams and oysters are filter-feeders, consuming the suspended single-celled plants—or algae—that grow in the seawater around them. The essential parts of their feeding apparatus are similar to a pump, which brings in large amounts of water and suspended foods; a filter, which retains the food but allows the water to pass out of the animal; and a conveyor belt, which transports food particles from the filter to the bivalve's mouth.

To feed the hungry shellfish, as many as 10 trillion algae cells per day are grown in a series of 52-gallon (200-liter) culture vessels, in a room where the air temperature is about 66 degrees (between 18 and 20 degrees C), and light is provided by fluorescent bulbs.

The Delaware scientists are using eight combinations of six algal species in test diets, to learn which combinations produce the best growth rates at all stages of oyster and clam development. Because the study has been conducted under controlled conditions, differences in survival and growth among the experimental groups of shellfish are known to be caused by the differences in their diets. Thus, the experimenters have been able to identify the algal diets that promote rapid growth. The species are easily cultured in the quantities needed for operating the shellfish seed hatchery and for other related experiments, although not in the numbers required for commercial operations.

One feeding problem confronting the Sea Grant team was to find a way of adding algae to the recirculating system without adding large amounts of the algal culture medium at the same time. The scientists have solved the problem, developing a new apparatus for harvesting relatively media-free algal cells. The culture medium is passed through a column of foam which traps the algal cells and carries them out through the top of the harvester. The culture medium trickles to the bottom and passes back to the culture tank.

A major barrier to the development of commercial closed-cycle aquaculture is that of farming the quantities of algae needed to produce large numbers of marketable shellfish. The Delaware group is now defining the conditions for more efficient growth of mass quantities and is cooperating with scientists at other institutions—including Dr.Curt Biddle of the NMFS facility at the University of Maryland—in a search for a suitable artificial feed.

Shellfish release fluid wastes from their kidneys, undigested wastes from their digestive tracts, and concentrate and reject fine particles of suspended inedible material. From the seawater in which they live, they extract calcium and other elements that contribute to their metabolism and growth. The presence of low levels of toxic substances, or small imbalances in the vital

Producing and Harvesting Seafood: How Much Does It Cost?

BY CHARLES E. EPIFANIO

(Dr. Charles E. Epifanio is an assistant professor at the University of Delaware's College of Marine Studies, and a biologist participating in the closed-cycle seawater aquaculture project at the College's Field Station, Lewes, Delaware.)

From traditional hunting and gathering to closed-cycle aquaculture, the various ways in which man obtains food from the sea can be placed on an energy-dollar cost continuum. The greater the dependence on natural phenomena to produce the food, the lower the cost. As man cultivates marine foods more intensively—decreasing his dependence on nature—the energy, and therefore the dollar, cost of production rises.

At the lower end of the production-cost continuum are the classical fishing methods, followed by transplantation, stocking of waters with hatchery-raised animals, enclosed hatcheries, and pond aquaculture. Topping this are totally recirculating systems of culture, such as that being developed at the University of Delaware.

The cost of harvesting, however, is lowest when marine organisms are intensively cultured in highly controlled systems. The dollar cost of harvesting by traditional methods is considerably higher and will increase as the cost of fuel rises. A cost-benefit ratio for any technique can be computed by comparing the energy or dollar cost of production and harvesting to the value of the ultimate crop.

One of the reasons why hunting and gathering is currently the most economical method of obtaining the majority of marine food resources is that there is little control of the rate of catch in the world's fisheries. But as fishing pressure increases, fish populations will become more limited, and the cost-benefit ratio of traditional harvesting methods will, in the long term, rise.

Aquaculture is practiced at many levels—some hardly distinguishable from hunting and gathering, others highly controlled processes.

Transplanting stock to new environments is a slightly more sophisticated form of hunting and gathering. It can be as simple as moving shellfish from seed beds to growing beds a few miles away, or it can involve attempts to introduce an exotic species thousands of miles from its native habitat. While transplantation affords man the energy advantage of being able to capture a desired food in a nearby environment, it can have disruptive effects on the local ecological community that may produce a long-term disadvantage.

Charles Epifanio checks temperatures in the hundred-gallon tanks where clam and oyster larvae grow until they are ready to undergo metamorphosis.

Both exotic and indigenous species of fish and shellfish have at times been cultivated in hatcheries and later stocked in marine environments. Although large energy inputs are required to rear the animals through their early life stages, increased survival of the young is an energy plus. But many of the desired species have considerable powers of locomotion. For example, shrimp—hatchery reared by one party—may be harvested legally by another if the animals stray into common waters.

An obvious solution to this problem is to gain control of large areas of water or bottom and exclude others from fishing there. If the species under cultivation can swim, the growers then have to devise ways to keep their stock within the controlled areas.

The energetic benefits of harvesting large crops of animals from relatively small proprietary areas are large. The drawbacks are equally imposing. Building and maintaining enclosures are expensive. Animals in this type of culture system generally need more food than is naturally available. Chemicals, sometimes used for keeping out predatory animals, may disrupt the ecology.

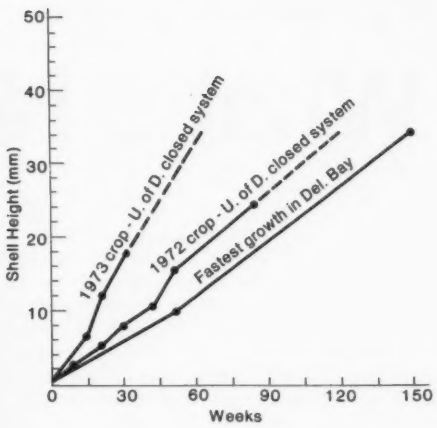
Furthermore, there are legal problems in leasing subtidal areas. In western cultures, subtidal land and the water above it are traditionally held in common by the people. Leasing subtidal land will be even more difficult in the future as the popularity of aquatic sports grows in the United States. Aquaculturists will find it hard to compete for space with recreational interests—until the United States experiences a severe food shortage.

A further step up on the continuum from hunting and gathering is the culture of high densities of organisms in ponds diked off from the natural environment. The energy costs of such construction are high, but the advantages in controlling growth and in harvesting are considerable. Most such ponds are built in salt marshes or mangrove swamps. The construction of many ponds in a single marsh probably would disrupt the marsh to the point of destruction. Since marshes are well known to be extremely important to the energetics of an estuary, the total effect of pond aquaculture in marshes may well be an energetic deficit to man.

Another disadvantage of high-intensity pond or raceway culture is that large numbers of animals grown in small areas produce large amounts of waste products. These effluents of high-intensity pond culture are essentially raw sewage. Untreated, they can create serious local environmental problems.

Self-contained, recirculating culture systems stand at the peak of the energy-dollar cost continuum. However, they are the least ecologically harmful aquaculture technique; they require no physical or chemical alteration of the wetlands or surrounding waters; and they do not compete with recreational interests. Growing conditions can be controlled almost completely, and harvesting the crop should be extremely efficient.

When all of these factors are considered, the feasibility of closed-cycle aquaculture seems evident. Growing clams and oysters in a controlled environment is potentially one of the most economical and ecologically desirable forms of aquaculture possible.



(Left) Research engineer Gary Pruder examines a group of oysters held in a specially designed rack that slides like a drawer into one of a series of growing tanks. (Above) Growth rates of aquacultured clams, in comparison with natural growth in Delaware Bay. Faster growth of 1973 crop reflects improved techniques.

constituents of the seawater, will slow their growth rate, make them more susceptible to disease, and lead to a low-quality product. Furthermore, unless great care is taken, the hardware in the closed-cycle aquaculture system may release chemicals poisonous to the shellfish.

High levels of toxic substances, or a serious imbalance of the cultural environment, will cause large-scale mortality in a short time, resulting in complete loss of the shellfish crop.

To maintain the water quality needed to produce marketable shellfish, the Delaware scientists are monitoring chemical components in the seawater that are critical to shellfish health and growth. They are examining methods for identifying and controlling the harmful chemicals. Other studies are investigating the animals' tolerance to various kinds and levels of toxins, to learn how much of which kinds must be removed from the water in the closed-cycle system. Soon, they expect to develop techniques for close chemical monitoring and control of chemical wastes. In another two years, it is hoped, the quality of seawater in the closed-cycle system can be kept at a level compatible with the culture of shellfish for commercial consumption.

The culture of algae, and the rearing of shellfish in closed-cycle systems, both provide ideal conditions for the growth of microbes. Microbiologists on the Delaware team are beginning to monitor the cultured shellfish and the seawater in the closed-cycle system for bacteria and viruses, to see if they are accumulating and to learn what corrective actions can be taken. The marketability of cultured shellfish will depend on the producers' ability to certify that they are free of bacteria that cause illness in the humans who consume them.

As the shellfish grow, tissue examinations and chemical analyses are carried out periodically, to determine their quality. When enough clams and oysters have attained market size, their quality will be compared with that of others grown in open waters. Characteristics such as flavor, color, texture, and appearance of the meats will be considered. Based on these tests, the culture system may have to be modified.

Other members of the first crop will be used in breeding future generations. In breeding and hybridization studies, biologists at the Lewes facility are searching for larger, faster-growing strains of clams and oysters. Northern and southern hardshell clams have been hybridized, and the growth of both the hybrids and the originals are being studied. So far, the northern hardshell clams are growing more rapidly, but this may be caused by the relatively low temperature of the water.

"Oysters," Dr. Price points out, "have a unique attribute that makes development of ideal specimens easier for the geneticist. All oysters begin life as males. When they are two or three years old, they become females. Thus, sperm from a young animal can be used later to fertilize its own eggs, and the result is an exact reproduction of itself."

Many questions of food and food production, water quality, disease, engineering, shellfish quality, and breeding still await answers from the Delaware team.

But already, they are initiating new investigations of marketing, legal, energy, and investment problems.

Closed-cycle aquaculture systems consume large quantities of energy: light for raising algae; heat for maintaining moderate temperatures and warming fresh water; and electricity for operating machinery and instruments. In cooperation with the University's Institute for Energy Conversion, the project this year will begin to examine the possibilities for using such natural sources as sun and wind to supply energy for commercial systems.

The laws of Delaware, Maryland, and Virginia are being analyzed to identify any legal problems—including the required permits and licenses—that might affect the establishment and success of commercial closed-cycle aquaculture.

Though a multitude of problems remains to be overcome, the Delaware Sea Grant team hopes, within three years, to demonstrate the dependability and effectiveness of large-scale, closed-cycle commercial shellfish aquaculture.

It's important to know

What's New On the Sun

BY LOUISE A. PURRETT

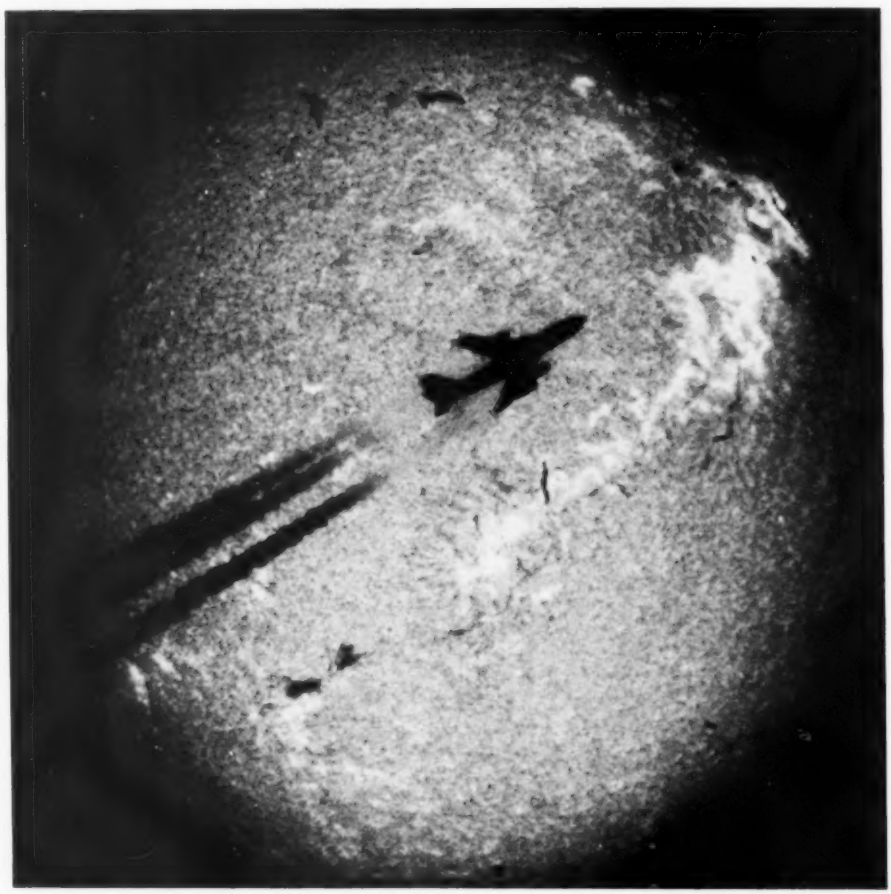
A storm on the sun millions of miles away may affect life on earth in a multitude of complex ways. Scientists are only beginning to understand how events such as solar flares reach out to disturb the earth's magnetic field, ionosphere, and, ultimately humanity's delicate creations. But what is known about the impact of solar events on the near-earth environment is now being systematically applied in attempts to forecast them. This is the job of the Space Environment Services Center, a weather service for space. The SESC in Boulder, Colorado, is the forecasting arm of the Space Environment Laboratory, one of NOAA's Environmental Research Laboratories.

"This is the only facility in the world dedicated to real-time monitoring of the space environment," says SEL Director Dr. Donald J. Williams.

Boulder's "space weather" center is the hub of a broad network of observation stations peering not at clouds and pressure areas, but at the sun and the parts of the terrestrial environment that the sun affects. From ground-based observatories and satellites, the space center receives around-the-clock reports on solar activity. "When the sun begins to act up, we know within a few minutes what's going on, and can tell what ionospheric and geomagnetic disturbances to expect before they occur," says Robert B. Doeker, head of SESC. The space weather people distil all the reports they receive and formulate 3-day, 7-day, and 27-day forecasts of solar and magnetic activity. The forecasts are then rapidly disseminated to 50 individuals and agencies.

The need to know what's going on on the sun and in the space environment, says Doeker, is in direct proportion to technological development. As a civilization becomes more complex technologically, its instruments may become more sensitive to changes in the environment. "A native living in a hut in the jungle doesn't need information on solar flares and magnetic storms. He couldn't care less. But if you have astronauts or delicate instruments up in space, or power lines running across the country, you become vulnerable."

The sun spews out a constant stream of charged particles and imbedded magnetic fields known as the solar wind. The solar wind beats constantly against the earth's magnetosphere, flattening it on the sunward side and hammering it into a long tail on the night side. Solar flares add their own touches to this constant stream, sending bursts of high- and low-energy protons, X-radiation, radio waves and ionized gases earthward, disturbing the Van Allen radiation belts, stimulating auroral displays, setting off magnetic storms, and posing a radiation hazard to life and equipment outside the shield of the atmosphere. Magnetic storms disrupt radio communications and induce ground currents in long electrical transmission and communication lines, frequently disrupting service.



Solar flares, which send bursts of high- and low-energy protons, X-radiation, radio waves and ionized gases earthward, pose a hazard to life and equipment particularly on high-flying aircraft on polar routes. NOAA's Space Environment Services Center, (SESC), headquartered in Boulder, Colorado, alerts supersonic transport programs so flights can be delayed or rerouted.

Recently evidence has been accumulating to suggest that changes in the space environment may even affect terrestrial weather. For example, says Williams, Walter Roberts of the National Center for Atmospheric Research has found a correlation between the severity of weather systems from the Gulf of Alaska and the occurrence of aurora. If the aurora is active when a storm is forming in the Gulf, the storm that eventually reaches the Rockies, for example, tends to be more severe. "So far, it's only a correlation," says Williams, "we don't know what is causing what. Does the aurora somehow intensify the storm, or does the growing storm sometimes stimulate the aurora?"

To answer such questions as well as compile its routine forecasts, the center depends on many and diverse sources. Optical observatories at Pakhua, Hawaii; Teheran; Athens; Ramey, Puerto Rico; Culgoora, New South Wales, Australia; and Boulder, send in three reports daily on the visual appearance of the sun—including such variables as the location of active regions, sunspots, or flares. Radio telescopes at the same locations report on solar temperatures, which follow 27-day and 11-

Dr. Donald J. Williams, Director of NOAA's Space Environment Laboratory, explains one of the satellites the laboratory hopes to send aloft. Called Plasma Instability Explorer ("PIE in the sky"), the satellite would stimulate the aurora with injections of cold ionized gas, or cold plasma, from a height of 20,000 miles above the geomagnetic equator.

year cycles. A rise in temperature may augur solar activity. "It's like putting a thermometer in the sun's mouth to see how hot it is," explains Doeker.

Other instruments monitor the various aspects of the near-earth regime that respond to changes on the sun. Riometers monitor the amount of cosmic radio noise that penetrates the ionosphere. This gives a convenient measure of its opacity, which increases during solar flares. Backscatter radar observes the location and intensity of the auroral ovals, the regions surrounding the two poles where auroras tend to occur. A global network of magnetometers monitors the earth's magnetic field. Five of them at Anchorage and Ft. Yukon, Alaska, Thule Geopole Station in Greenland, at Vostok in Antarctica, and in Boulder, send in their measurements in real time. A variety of ionospheric sensors look for rapid changes in the ionosphere. Several ionosphere observatories also report their data in real time.

Earthbound sensors can supply only part of the picture, however. The earth's atmosphere and magnetic field screen out most energetic solar particles and X-radiation. The solar wind exerts most of its influence high above the earth in the ionosphere and upper reaches of the magnetosphere. Satellite-based sensors orbiting above the blanketing atmosphere provide data unattainable from earth.

Currently, the satellites most helpful to the space weather scientists are those in the SMS/GOES* series. The first of these, SMS–1, was launched last spring into a circular orbit around the equator. Another was launched early this year. The orbital speeds and altitude of the SMS/GOES satellites are matched with the earth's rotation, so that each satellite remains poised some 22,300 miles above the same spot on the earth's equator. Instruments on SMS/GOES monitor changes in the geomagnetic field and the flow of energetic material—X-rays, protons, and electrons—from the sun. The information is beamed to an antenna located on Table Mountain north of Boulder, and telemetered from there to the forecast center. The data flow in on a 24-hour basis in real time. "SMS/GOES represents an enormous step forward in monitoring and short-term prediction," says Williams.

SMS–1 was put to a practical test very soon after its launch. In July, the sun began acting up in earnest, with the most violent outbreak of solar activity since the great flares of 1972. When these major flares developed, the Soviet Union had some cosmonauts in space. Williams recalls, "We got a request through diplomatic channels for GOES data on radiation levels. Fortunately, it turned out that there was no real danger."

SMS/GOES is currently the space forecasters' main vantage point in space, but it's not the only one. For example, a series of low-altitude, polar-orbiting satellites, called NOAA and operated by the National Environmental Satellite Service, carry solar proton monitors to measure the energetic particles from solar flares as they impact the polar atmosphere directly. The DMSP satellite, operated by the Department of Defense, has particle and X-ray sensors and, in addition, a very sensitive television system that returns photos of the aurora. Both provide the SESC with valuable data on a near real-time basis.

The first of a new series of low-altitude weather satellites, TIROS–N, scheduled for launch into a polar orbit in 1977, will open up another window in space for the SESC forecasters. A team of SEL scientists is designing a Space Environment Monitor to fly on the satellite being built to NOAA specifications by the National Aeronautics and Space Administration. The monitor will include sensors to measure protons and electrons at various energies over a wide energy range (500 to 1 billion electron volts). At the low-energy end of this scale, a total energy detector will measure the total energy deposition into the upper atmosphere due to charge particles. At the high-energy end, instruments will monitor for the first time solar flare particles capable of producing dangerous radiation levels at altitudes of high-flying commercial aircraft. In the middle energy range, instruments will continue the work of the present NOAA satellite

**From Synchronous Meteorological Satellite (NASA's designation for the research and development models) and Geostationary Operation Environmental Satellites (NOAA's designation for the operational spacecraft).*

series in monitoring solar flare particles impacting the polar atmosphere.

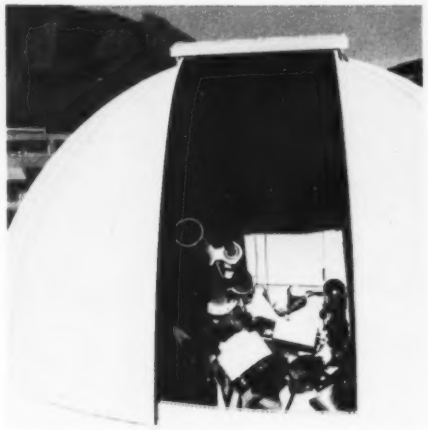
"TIROS–N gives us our first opportunity to monitor in near-real time those energies responsible for phenomena of vital importance to our Space Environment Services Center," says Williams—these phenomena range from possible radiation hazards to those particles that interact with the upper atmosphere over polar regions to produce spectacular auroral displays. Williams also hopes TIROS will allow direct tests of the relationship between auroral and severe storms in the Gulf of Alaska.

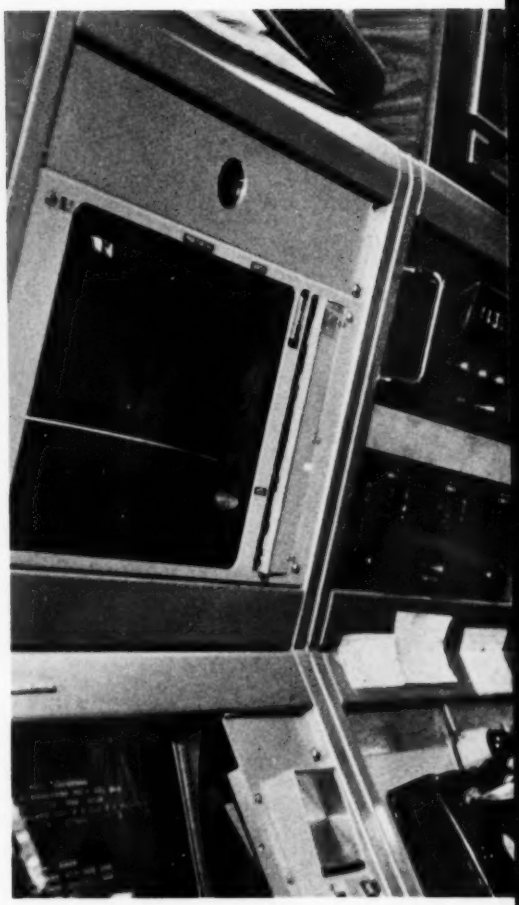
Combining information from all these sources, the space weather forecasters compile periodic reports and predictions on solar and magnetic activity. Doeker compares this "bread-and-butter" service to the "washday forecasts" of the Weather Service. Just as a housewife could tune in the radio for a weather report before hanging out the wash (in the days before electric dryers), power companies or space operational personnel can phone the SESC for a prediction of magnetic and solar weather that might affect them. The regular solar forecasts are sent by mail and teletype to a list of users—government agencies such as the Federal Aviation Administration and the Canadian Department of Energy and Natural Resources, ship commanders, aircraft corporations, power companies, research laboratories—anyone whose activities might be affected by changes in the space environment. In addition, an "alert" system provides immediate, day or night, telephone notice of abnormal activity, such as major solar flare, much like the Weather Service's hurricane and tornado warnings.

The exploration of space provided not only the tools for better space environment monitoring, but also the impetus for reliable information and forecasts. Planners of manned space missions needed to know the amounts and types of radiation astronauts would encounter in space. "If our astronauts were on the moon during a major solar flare, they would have been exposed to dangerous radiation," explains Doeker. The SESC was instrumental in helping Mission Control Center, Johnson Spaceflight Center, plan flights during the Apollo missions. The collaboration between the space weather forecasters and space flight planners in the Apollo Project was so successful that SESC was later asked to provide the same service for the Skylab Project.

During the Skylab missions, project scientists collaborated with SESC forecasters to decide what the astronauts should do—for example, where on the solar disk to train their instruments during a given day. Doeker compares the Center's role in such space missions to the Weather Services' telling an airline pilot where he might expect to encounter turbulence and recommending an alternate course.

"Our people participated intimately in planning the Skylab mission," notes Williams. "We played a supporting role, monitoring radiation hazards and the state of solar activity during the mission. It was a valuable experience for us, as well: we learned a lot working on it."



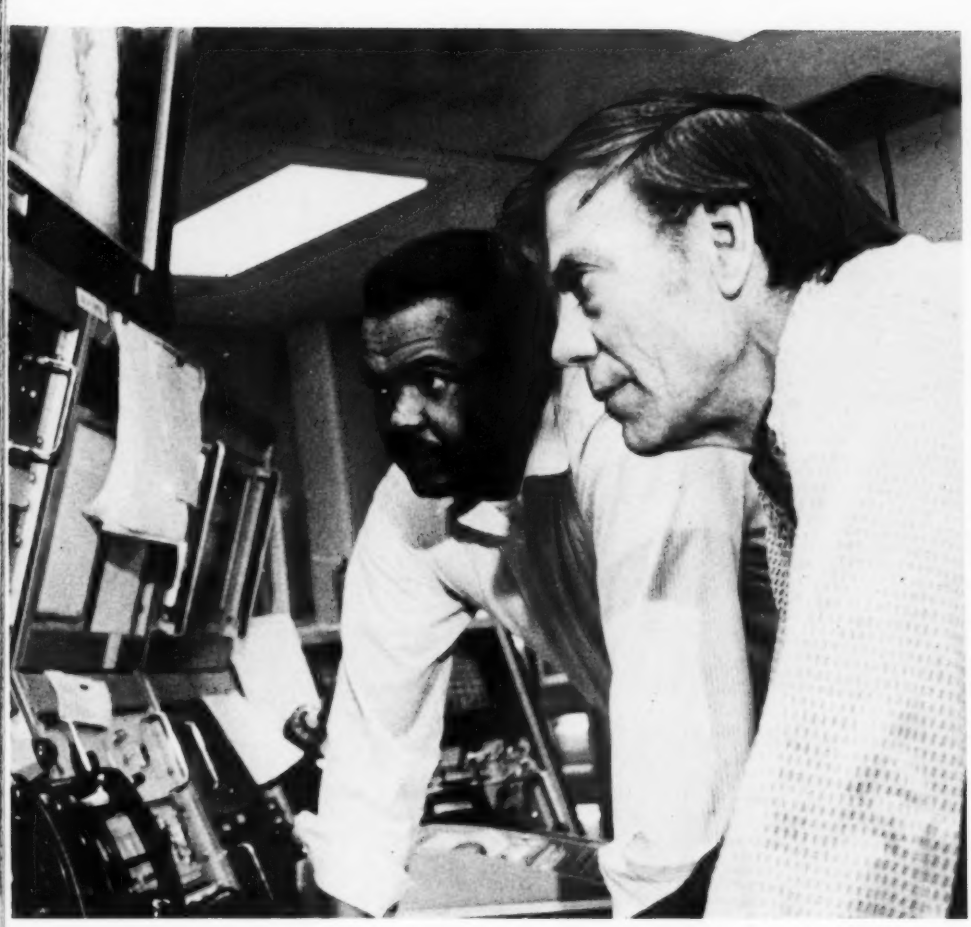


Alvin Gray of SESC (above left) scans data from SMS/GOES. With only a telephone and teletype like this, anyone in the world can contact the Boulder computers for solar and magnetic information. Optical observatories (below left) keep a constant eye on the sun for NOAA space weather forecasters. Robert Doeker (right), head of SESC, and forecaster William Flowers examine a television image of the sun relayed from the observatory atop the laboratory roof. Data on the state of the sun, ionosphere, magnetic field, and x-rays and charged particles flows steadily into the forecast center.

The space weather service also helps protect passengers on certain lower-flying craft. In polar regions, the earth's magnetic field, which helps shield the rest of the globe from high-energy particles generated by solar flares, dips toward the earth, allowing such particles to penetrate deep into the atmosphere, reaching altitudes traversed by high-flying aircraft. Passengers on supersonic transports and jumbo jets on polar routes could thus be exposed to hazardous levels of radiation. "The jumbo jets fly at lower altitudes than supersonic planes," explains Williams, "but they are also slower, so the actual dosage of radiation could be the same, since they remain longer in the path of solar particles." So the SESC keeps supersonic transport programs posted on the level of energetic particles at the poles. "We provide alerts and real-time data that allow them to make course adjustments to avoid a potential hazard," says Williams.

Other services are more down to earth, but no less vital. "As advanced nations began putting in long high-voltage power lines," says Doeker, "utility companies began to have some funny problems. Safety relays in transformers along these lines would trip, cutting off power transmission. Repairmen would come out to check, find nothing wrong, and turn them back on. What was happening was that large geomagnetic storms would induce electrical currents in the ground, and in buried power lines. If the induced current gets strong enough, it trips the safety relays. That was why the repairmen found nothing wrong when they went out to look. The trouble is, if there is a genuine malfunction and the current is turned back on, the transformers could blow, causing half a million dollars' damage. Now when their circuit breakers are tripped, utility companies check with us; they would rather be safe than sorry."

The space weather center's newest customers, says Doeker, are pipeline companies. The natural corrosion of underground pipes is aggravated under certain ground to



pipe electrical conditions. If the wrong electric charge is placed on the pipes during a magnetic storm condition, the corrosion may be enhanced for long periods after the storm has subsided. A check with SESC helps avoid such calibration mistakes.

In mid-1976, the space weather people will take on another challenge, when they join a three-year international study of the earth's magnetosphere, the International Magnetospheric Study. Most of the major nations will be involved in this massive program, says Williams. Participating nations will link their existing satellite and ground facilities in a common network and a common effort to understand the physical phenomena of the magnetosphere. Several nations are planning new observation platforms for the experiment: some 20 magnetic observatories have been recommended to supplement the U.S. ground-based network. The European Space Research Organization (ESRO), the United States, Japan, and the Soviet Union will launch new satellites.

The magnetosphere acts as the arbiter in interactions between earth and sun, determining how events on the sun, such as solar flares, will affect the terrestrial environment. Space scientists now have a good understanding of the overall configuration of the magnetosphere. The major dynamical phenomena have been classified and there is general knowledge of where and when important events take place. The next step, the purpose of IMS, is to understand the detailed mechanisms that result in the observed features and the physical interactions that bring them about, and to define the cause and effect relationships.

NOAA's Space Environment Laboratory will play a central role in the study. SEL has been asked to perform the real-time data operations for the study, serving as a central clearinghouse. Dr. Robert Manka, who joined the SEL staff in February, is the U.S. Coordinator for the project, working through the National Science Foundation in Washington.

For all its growing sophistication, the SESC is still in its adolescence. Williams and Doeker see many parallels between their service and the development of the meteorological services. Both began with essentially empirical observations; the understanding of physical processes at work and causal relationships resulting in improved forecasting capability comes later.

Early farmers could see a ring around the moon or dark clouds approaching and make fairly reliable weather predictions based only on folklore and past experience, without knowing anything about pressure systems and cloud dynamics. Similarly, space forecasters know that a flare on the sun is followed by a magnetic storm on earth, though the exact processes at work are imperfectly understood.

Part of the problem is that SESC is still at the single-station contrasting stage, says Doeker. "We have to figure out what's going on from what we can see from one vantage point." In monitoring the space environment, scientists are still at the single-station analysis stage. The earth, and the satellites in the immediate vicinity of earth, constitute one station looking out in space.

"We have a few observatories; the Weather Service has many," continues Doeker. "They are tied together with a world wide communication network; our communication link is the telephone. The meteorological community has pushed forward with theory and models that are now widely applied. Theoreticians in space forecasting haven't made those breakthroughs yet. We are still largely dependent on experience, empirical rules, extensive monitoring. We use a computer as a logger and sorter; meteorologists use it for modeling. We're a molehill to their mountain."

But that state of affairs is changing. In many ways, NOAA's space weather service stands on the threshhold of new developments. New tools and vantage points are rapidly becoming available. For example, a new West German research spacecraft, called HELIOS, launched in December, will in effect give the space scientists a "second station" in the solar-terrestrial system. HELIOS is in a highly elliptical solar orbit and aboard the ship are particle, solar wind, and magnetic field sensors that will provide an invaluable measurement of the environment near the sun.

SOLRAD-HI, a Navy satellite pair scheduled to be launched into orbit at a height of 20 earth radii in November, will provide the Boulder facility with real-time data on X-rays, protons, electrons, and, most important to the forecasters, solar wind data.

Williams foresees some important theoretical advances in the next decade. It should be possible within the next couple of years, he believes, to begin operational prediction of low-energy solar proton events in the energy range responsible for polar cap absorption, intense absorption of radio waves in the auroral zones.

One of the long-range goals of the Space Environment Laboratory has been the development of a Solar-Terrestrial Environment Model (STEM). This ambitious project is aimed at numerically simulating solar flares, followed by the injection of flare-associated energy into, and propagation through, the interplanetary medium, the transfer of this energy into the magnetosphere and its disposition within the magnetosphere, the ionosphere and the atmosphere. Williams says the SEL scientists now have the theoretical capability to formulate parts of the STEM. "We have the basic knowledge. All we need are the resources to carry it out." The complete, operational model, Williams predicts, may well be 20 or 30 years in the future.

When the Solar-Terrestrial Environment Model is a working reality, forecasting of solar events and magnetic storms will no longer be an empirical craft, but a theoretically based science.

In case you can't wait, it's 29° 44' 26" by 80° 44' 52"

The Great Red Snapper Sink

BY RAYMOND WILCOVE

About 25 miles off the coast of Florida there's a hole in the bottom of the Atlantic Ocean deep enough to hold a skyscraper. No one knows how deep it is.

It is termed a sinkhole by geologists because such holes are formed by the collapse of the roof of a cavern which has been dissolved out of the underlying limestone in the Continental Shelf by underground water. This particular sinkhole is believed to have been formed many thousands of years ago when the land was above water.

Several expeditions to plumb its depths and unravel its mysteries have proven only partially successful. Oceanographers have established that it is at least 465 deep, but fishermen's reports of much greater depth are credible because the hole may angle off slantwise and only a lucky sounding could find its way down to the bottom.

The sinkhole was first discovered in 1962 by a commercial fisherman who caught about 5,000 pounds of red snapper fish in it before a storm drove him away. It remained lost until 1968, when several fishermen rediscovered it. Some 100,000 pounds of red snapper fish were reportedly removed over a six-week period. Since then the hole has been known as Red Snapper Sink.

There are other sinkholes off the Florida coast and commercial fishermen are continuously on the search for these "gold mines" at the bottom of the sea. When they're found, it's a closely kept secret because, unlike gold mines on land, these holes can not be staked out.

Rumors of the 1968 find began drifting around in 1969 after the hole had been depleted of its vast horde of fish. In 1970, the U. S. Geological Survey mounted several expeditions to the site, guided to the scene by the men who had rediscovered the hole, Captains W. L. Stevens and Gordon Witmor of St. Augustine, Fla. It was during the 1970 expeditions that the GS party, headed by Dr. Frank Kohout, a hydrologist engaged in salt water studies and an authority on sinkholes, determined that the hole was at least 465 feet deep.

Last June, the National Oceanic and Atmospheric Administration sent an expedition to the scene to chart the hole. As a result of its survey, the location of Red Snapper Sink will now be noted for the first time on the nautical chart for the area which will be issued by NOAA's National Ocean Survey. For those fishermen who can't wait for the new chart and who would like to try their luck at the hole, the coordinates are 29° 44' 26" N. latitude and 80° 44' 52" W. longitude.

Hydrologist Warren Leve examines fathometer showing two passes over Red Snapper Sink, on board vessel belonging to Marineland of Florida. Oceanographers have established that the Red Snapper Sink is at least 465 feet deep but fishermen's reports of much greater depth are considered credible. (Photo: Dr. Frank Kohout.)

The NOAA/USGS expedition was conducted by a five-man contingent of the National Ocean Survey's Atlantic Hydrographic Party, based in Norfolk, Va., led by Lieutenant Commander Fidel Smith. The party included three GS personnel, led by Kohout.

From the investigations so far conducted this much is known of Red Snapper Sink:

1. It is located about 26 nautical miles east of Crescent Beach and approximately 30 miles southeast of St. Augustine.

2. It lies in water generally about 88 feet deep. However, the sink hole is in a depression shaped like a funnel that slopes gently down from 88 feet to about 150 feet, where the shaft of the funnel begins to drop vertically through the sea floor to at least 465 feet. Whether it goes deeper is not known.

3. The hole's diameter at the 90-foot contour (just inside the edge of the funnel) is 400 feet. At the 150-foot contour, the north-south diameter is about 130 feet.

4. The shape of the vertical shaft is not known. Scuba diver Robert E. Hill of Merritt Island, Fla., who accompanied Kohout on the 1970 trips, reports that there were ledges and overhangs down to his maximum diving depth of about 300 feet. The hole may have narrow and wide passages, like those found in caves on land. One theory holds that it is not a vertical hole, but slants off at an angle at some depth. Attempts by the NOAA/GS expedition to try and "snake" a line through it with a fishing weight to a deeper depth proved unsuccessful.

Last year's expedition was conducted from aboard the 60-foot Launch 1257. As the launch drifted slowly across the hole or remained stationary, the depth was recorded on a fathometer, an electronic instrument which determines depth by measuring the time it takes an echo to travel to the sea bottom and return. The fathometer recorded a depth of 438 feet, but due to side echoes from such a steep-walled hole this could represent somewhat less than the total depth.

According to Kohout, the most valid depth was recorded in 1970 by Frank T. Manheim, a geochemical oceanographer with the U.S. Geological Survey, now with the University of South Florida, and G. Warren Leve, a GS hydrologist stationed at Jacksonville, Fla. They employed a cable and obtained a depth of 465 feet. Kohout questioned the reliability of depths of 600 to 700 feet reported by a fisherman.

But both Smith and Kohout were agreed that the bottom depth had not been confirmed. "The exact depth of the sink has not been resolved," said Smith upon conclusion of the expedition. Smith recommended that if another attempt is made, a vessel with more sophisticated electronic sounding equipment be used. Kohout suggested that a submersible could probably maneuver far enough down the hole to determine its depth and shape.

One thing the expedition did determine last year, which had previously been in doubt, was that the hole was not a fresh water spring. Considerable fresh water is known to exist beneath the sea bed off the Florida coast and it is possible that Red Snapper Sink might have discharged fresh water in the past. However, none of the water samples collected at a depth of 420 feet showed any trace of fresh water.

Indicative of the fresh water underlying the continental shelf off Florida, a well drilled about 25 miles from Jacksonville discharged fresh water from depths of 390 to 750 feet below sea level. Other test borings have indicated that relatively fresh water extends to the edge of the continental shelf about 75 miles from shore, as reported in a paper prepared by Leve, Manheim and Kohout for delivery at the Second International Ground Water Symposium at Palermo, Sicily, in 1973.

Kohout reported in the Encyclopedia of Earth Sciences that the most famous submarine springs are probably those of Bahrein in the Persian Gulf. Divers formerly collected the fresh water in goatskins and the highest price was paid to the water vendors who

mixed in the least amount of sea water.

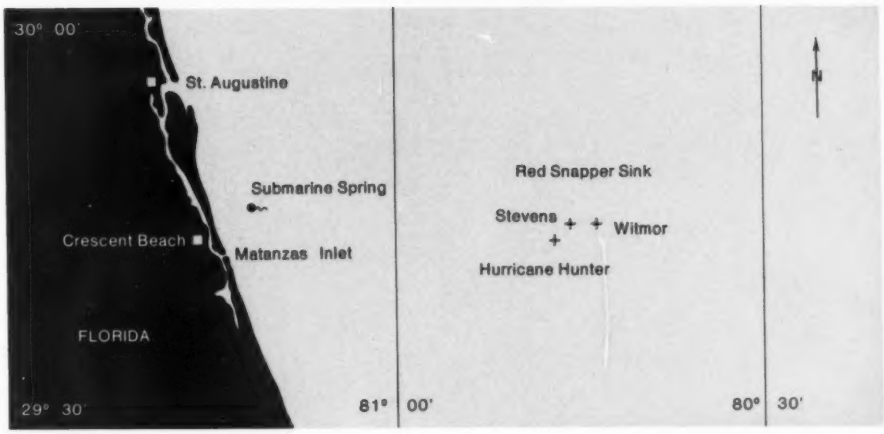
Kohout said there are numerous submarine springs on both the east and west coasts of Florida where the discharge is generally brackish and occurs through round sink-like holes on the continental shelf in 50-foot depths. A submarine spring discharges fresh water 2½ miles off Crescent Beach through a sink-like crater about 126 miles below sea level. The continental shelf in this area off the Florida east coast is about 55 feet below sea level.

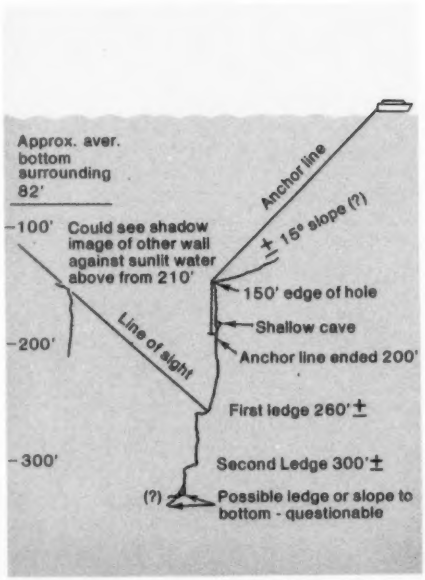
Kohout said there are also hundreds of holes off the Bahamas which discharge water. They are known variously as "ocean holes," "boiling holes" and "blue holes." Hot and cool submarine springs have also been reported in Hawaii, Japan and other Pacific volcanic islands.

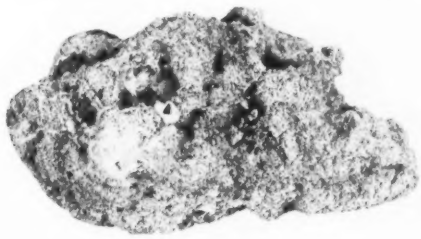
The Geological Survey hydrologist said it is not known why fish congregate in such large numbers in sink holes, but speculated that they might be seeking refuge there from predators or might be attracted by a food chain generated by nutrients which flow up from the sea bottom.

But regardless of why they are attracted to the sinkholes, they furnish a source of considerable wealth when discovered. According to NOAA's National Marine Fisheries Service's Market News, commercial fishermen in Florida received 82 cents a pound for red snapper last December. Kohout said some of the fish taken from Red Snapper Sink weighed 20 to 25 pounds.

Participants in the NOAA/USGS expedition to Red Snapper Sink included Lieutenant Commander John O. Rolland, in charge of the launch, Lieutenant Junior Grade Richard P. Floyd, D. Mason and W. Sprye, in addition to Lieutenant Commander Smith, from the National Ocean Survey, and G. W. Leve, M. Backer and Frank Kohout from the Geological Survey.







(Top) NOAA Launch 1257 in rendezvous with fishing boat over Red Snapper Sink. Map shows LORAN locations of sink prior to NOS-USGS survey, and sketch below is sketch by SCUBA diver Robert Hill of Sink, made during his June 21, 1970 dive. Shellen crusted rock was collected at 200 foot depth in Red Snapper Sink during dives to learn more about the mysterious hole in the bottom of the ocean. The deep holes apparently attract numerous fish since some 100,000 pounds of snapper were taken here during a six-week period.

A vast outdoor laboratory provides the setting for an

Oklahoma Storm Watch

Spring winds flow almost perpetually across the Great Plains, their velocities modulated by the highs and lows which march eastward across the prairie. Sometimes air flows from the wet Gulf, sometimes from near-deserts west of El Paso. Sometimes cold air moves in and shoves the warm flow back into Texas.

By May the center of maximum severe thunderstorm and tornado activity has shifted from the southeastern states to the hot open country of the southern plains, and northward. On the average, from May through June, the Oklahoma winds carry more and more severe storm activity, along with nature's especially unfriendly phenomenon—the tornado.

If there is anything like a greeting for these unwelcome atmospheric visitors, it comes from scientists at the National Severe Storms Laboratory, one of NOAA's Environmental Research Laboratories, in Norman. People here, in May, look toward incoming storms with an interest that blends the largely intellectual matter of learning more about these storms with the assorted feelings of impending combat. It happens every spring, and each severe storm that falls into their observational ambush contributes to man's ability to anticipate, detect, and give timely warning against destructive thunderstorms and tornadoes.

"These spring experiments," says Dr. Edwin Kessler, director of the Oklahoma laboratory, "are a basic source of data for the continuing study of severe thunderstorms and tornadoes in the United States. Each year we go into the field a little bit better equipped in terms of scientific knowledge and instrumentation, and each year we get a little closer to being able to say when and where a severe storm will occur, and whether it will spawn a tornado."

To continue the learning process this year, NOAA scientists have assembled what are probably the best storm-watching tools present-day science and technology can provide. A large piece of Oklahoma has been transformed into an enormous outdoor laboratory, dotted with surface instruments, and eventually to be crisscrossed by research aircraft, now waiting on the aprons at Westheimer field and Tinker Air Force Base, some 20 miles away. Communications links tie the Norman laboratory to the Weather Service's National Severe Storms Forecast Center, in Kansas City, Missouri, where the country's operational watch and warning activities begin, and to National Environmental Satellite Service people there who transmit incoming images from the geostationary satellites which watch the midwestern skies from a vantage point 22,000 miles out in space. Of course the spring program provides an important base for the testing of varied new technology. In addition to forecasting tests with improved satellite photography, there is an anemometer experiment developed by the Wave Propagation Laboratory to measure horizontal wind and wind divergence; another experiment by Dr. Peter Kuhn of the Atmospheric Physics and Chemistry Laboratory is carried aboard a NASA Convair 990 and uses infrared radiometry to produce high resolution surface temperature measurements. And a lidar installed by the National Center for Atmospheric Research at NSSL's tower site will measure the atmospheric aerosols as part of an effort to trace thunderstorm air to its sources.

However, the centerpiece of the spring experiment is housed in a large white geodesic dome mounted on a blue pedestal, visible for miles. This large radome houses half of the NSSL's first line of intellectual offense against tornadoes developed thus far—the dual Doppler radar. Inside the radome a 30-foot radar dish moves with the ponderous grace of very heavy things, delicately poised. A second, nearly identical system at Cimarron airport, about 25 miles to the northwest, does the same. This 10-centimeter dual Doppler system is the only one of its kind permanently deployed.

Choice of wavelength is important. Although smaller wavelengths have better resolution—that is, they "see" smaller objects—and their antennas can be more readily transported, their waves are substantially absorbed by dense water and ice targets common in severe storms. Moreover, the Doppler feature at this wavelength provides unambiguous measurements of larger velocities without sacrificing radar range coverage. This attribute becomes critically important in observation of large convective storms in which velocities often exceed 30 to 40 meters per second and have intricate spatial structure. The large antenna with the advanced 10-centimeter system developed in Norman provides resolution of features almost down to tornado size—tornado funnels are typically less than half a mile across and the 10 centimeter wave can penetrate a severe thunderstorm cloud system without much loss of signal. Having two radars allows for combination of velocities of raindrops or airplane-deployed chaff with respect to each radar. This makes it possible to obtain true wind speeds and directions throughout the storm system being observed by both radars. Systems are being developed to give each radar realtime displays of Doppler data.

Severe storms present extremely complex and often short-lived processes at every stage of their life cycle, but rapid acquisition of comprehensive information on winds and reflectivity with Doppler radar is beginning to provide detailed data on wind velocity and condensate distribution which have been hitherto poorly known.

For example, in data analyses recently completed by Rodger Brown, we now begin to see the tornado whirlwind or vortex much more clearly in its relation to the larger rotating circulation called a tornado cyclone. Brown notes that a better understanding of how these two scales of activity are related should prove important to improving forecasts and warnings.

Researchers have identified a characteristic Doppler signature of rotation in a tornado-producing thunderstorm. As with the "hook echo" signal often observed on conventional radar displays, it is practical to display this more definite indication of rotation in real time as an aid to better forecasts.

But numerous other relationships are also being explored here.

"We also want to identify and interrelate surface manifestations of severe storms—gust fronts, hailfall patterns, heavy rain, tornados—so that we can better infer a storm's severity from a few clues," Dr. Kessler explains. "And we expect to develop better descriptions of storm energy and moisture budgets, energy transfer between the thunderstorm and its environment, and the larger-scale processes which

When a tornado ripped through the tiny town of Union City, Oklahoma, on May 24, 1973, it was observed and photographed by a team of storm-chasing meteorologists from NOAA's Environmental Research Laboratories' National Severe Storms Laboratory located in Norman, Oklahoma. This photograph (top) shows the mature funnel as it entered Union City. Above, the storm pursuit group sets up to record a developing tornado on high-quality cameras from the National Aeronautics and Space Administration. (Photos taken during 1973 Union City storm, courtesy of Robert Gannon.)

Far left, one of a pair of 10-centimeter-wavelength Doppler radars; left, Dr. Dusan Zrnic, Dr. Stanley L. Barnes (standing), Steve Nelson, Ron Cole, J. T. Lee, and Tom Jobson, (in background) in control room at Norman, Okla.; above, J. T. Dooley controls link between Doppler radar facilities; below left, instruments monitor winds, moisture, and temperatures with some telemetering directly to Norman.

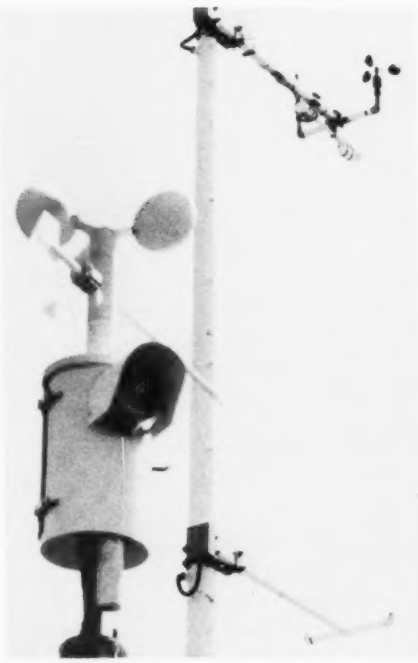
contribute to storm formation."

The laboratory is also studying patterns of turbulence in and around thunderstorms, with an eye to improving aviation guidelines relating to flight safety near severe thunderstorms. This continues the work of Project Rough Rider, under the direction of J. T. Lee, and takes instrumented jets into the heart of these storms.

Thunderstorm penetration aircraft have included the Colorado State University F-101 and various types of jet fighters on loan, with a chase plane, from the Air Force 4950th Test Wing at Wright-Patterson Air Force Base, Ohio. Larry A. Roberts, the civilian engineer aboard the RF4C Phanton used last year, provided these impressions of a thunderstorm turbulence mission.

"When telephone conversations with the National Severe Storms Laboratory indicate that 'scramble' is probable, all the people associated with the project gather in or near base operations at Tinker Air Force Base. When I receive the word to go, I pass the word to the group and then head for the airplane. As we roll out of our parking slot the pilot activates a switch on his instrument panel labeled AIR TURBULENCE TEST. A light glows on my test instrumentation control panel indicating that test electrical power is now available. For the next few minutes I turn on various items of instrumentation, check their operation, and perform calibration cycles. One item of particular importance is setting up a time-code generator. This device puts clock time in hours, minutes, seconds, and milliseconds on my data tape so that I can correlate it with the radar tape recorded on the ground at the severe storms lab during the mission.

"By the time these tasks are complete, both the chase aircraft and the penetration aircraft are on the runway. The chase plane



takes off first. We follow 15 seconds later and climb out in formation.

"As soon as possible after breaking ground, we leave the Oklahoma City Departure Control frequency and go over to Rough Rider Control. This is an FAA controller at the laboratory in Norman. He tells us he has radar contact and gives us an initial vector to the target storm system. Enroute to the storm, the pilot performs a calibration maneuver—a sinusoidal climb and dive maneuver—designed to check our test instruments and sensors. When we reach the general area of the target storm, Rough Rider Control directs the chase plane to break off and places him in a holding pattern in the clear. The Phantom pilot and I complete our prepenetration checklists and then wait for vectors from Rough Rider Control for our first pass through the storm.

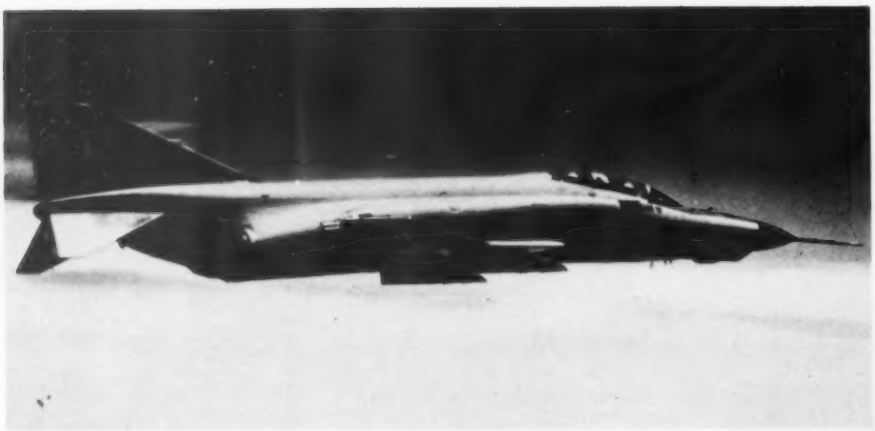
"For data purposes, the actual penetration begins with a time hack from Rough Rider Control which is given approximately one minute before we actually enter the storm. A similar time hack, which is given about one minute after exiting the far side of the storm, ends the penetration.

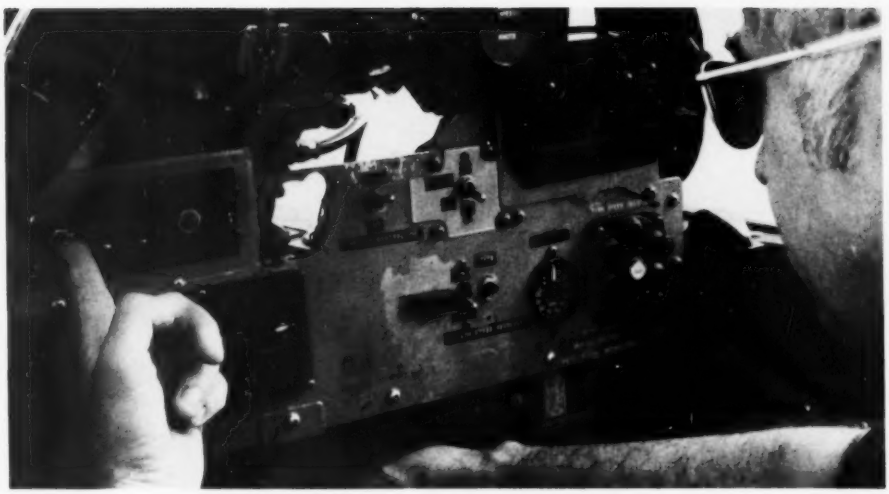
"After the final storm penetration, Rough Rider Control gives us a heading for Tinker and then brings in the chase airplane to look us over. The chase pilot sees no significant damage so we return to the base in formation.

"As soon as the engines are shut down on the ramp ground crew people are crawling all over the airplane checking for damage. They find a few dents and paint scratches from the hail and evidence of several lightning strikes. They begin making temporary repairs immediately. A fuel truck stands by. Instrumentation personnel reload the data recorder in the nose. In 45 minutes we're ready to go again."

Another mobile element of the yearly observational program at Norman are the radio-equipped, camera-laden vans used by tornado intercept teams from the NOAA laboratory and the University of Oklahoma. This year they will be joined by the Hail Study Unit from NCAR directed by Drs. Charles and Nancy Knight. Their job is to close with the developing tornado, and capture evidence of the twister's life cycle with hail preserving flasks and high-quality cameras made available to the project by the National Aeronautics and Space Administration.

On May 24, 1973, the intercept unit got to





Penetration aircraft in flight; above left, Air Force project engineer Larry A. Roberts, shows NOAA's Jean T. Lee, aeronautical coordinator, the panel; above, Roberts at his second-seat position in the aircraft; top right, Lee and Air Force pilot Major James Brenholdt stand beneath the arrow symbolizing penetration flights. The tail insignia shows the two "T's" of thunderstorm turbulence.

within three miles of a large tornado which twisted to earth near Union City, Oklahoma, wrought a catastrophe through that tiny community (population 500), and died over the prairie west of Oklahoma City. The result of this windy day's work was man's best look thus far at the birth, life, and death of one of nature's most destructive phenomena, and the first measurements ever made of tornado wind speeds at different times in the life of the twister. The first results of the laboratory's extensive study of the Union City tornado were reported late in 1974.

"For several years," says Dr. Joseph H. Golden, who leads Storm Intercept, "we've suspected that winds in the most severe tornadoes are probably not much more than about 200 miles per hour. This work points in that direction."

Photogrammetric analysis of the Union City footage, done by tracking from frame to frame easily identifiable cloud "tags" and debris outside the funnel proper, showed this distribution of winds. Wind speeds of from 140 to 185 miles per hour were observed in the large debris cloud about 300 feet above the ground, and extended outward from the funnel walls from 650 to 820 feet. At the same time, cloud tags rotating around the upper periphery of the tornado funnel had horizontal windspeeds of 10 to 100 miles per hour at distances of from 1,300 to 2,300 feet from the tornado's center.

Calculations of vertical windspeeds indicated upward motion in the debris cloud of about 30 to 70 miles per hour below 330-foot heights, and 23 to 35 miles per hour in a "feeder band"—a cloud spiral running from the upper portion of the funnel into the larger, parent circulation in the tornado-spawning thunderstorm.

These results are similar to the only other photogrammetric tornado wind measurements, those made from newsfilms of a Dallas tornado 14 years ago.

One surprising finding was that there was no correlation between the width of the tornado (the visible condensation funnel) and the severity of the damage along the path of the funnel.

"In the case of the Union City storm," Golden explains, "the tornado funnel diameter ranged from 300 to 1,600 feet near the top. As it entered the town, the funnel shrank rapidly in diameter at all heights, its top tilted much more toward the northeast, and the tornado turned suddenly to the southeast, accelerating to a forward speed of 25 to 30 miles per hour. However, the maximum winds we observed didn't change very much with this shrinking, and the damage along the narrower path of the storm was still quite severe."

The Union City tornado study also indicates that tornadoes and another, less-violent atmospheric whirlwind—the Florida waterspout—may share similar life cycles.

"In many tornadoes," Golden explains, "before we ever see a funnel cloud we see the storm beginning as a kind of oversized dust devil at the surface. This corresponds to the dark spot seen on the ocean surface before waterspout funnels form.

"We also get similarities in the mature and decay stage. Usually a waterspout decays abruptly as an advancing rainshower overtakes it from the rear. In the Union City tornado, heavy rain and hail to the north began to overtake the funnel, which became contorted and ropelike, and then dissipated."

This suggests that the tamer waterspout would be an extremely valuable "surrogate" tornado for severe storm researchers.

On a typical day, about mid-morning, data from Kansas City and a computer, or "objective," analysis of atmospheric conditions at the laboratory may suggest the possibility of severe afternoon thunderstorms. Since these first indications, the increasingly cloudy arm of a cloud front swinging southwestward from a low-pressure system over western Kansas has intensified as converging warm and moist, hot and dry, and cool air masses transform water vapor and heat into energy. The frontal band of cumulus clouds grow toward thunderstorms.

By early afternoon project scientists are filtering the mass of incoming surface and upper-air weather data very carefully, in an effort to read the atmospheric future. The bulletin board alert sheets draw a larger crowd. There are more people in the laboratory building's data room, where continuous readouts from sensors on a television tower

north of Oklahoma City, computer drawn wind and temperature maps of the Oklahoma atmosphere, and the storm-tracking sweep of a digitized WSR–57 weather radar are available for viewing. As the squall line cuts into western Oklahoma, the center of action moves to the Doppler radar building in Norman.

The project control room is housed in the large blue cylinder which supports the radar antenna pedestal. There, Federal Aviation Administration radio and radar links provide air traffic control for the airplanes the laboratory will launch today. The realtime readouts from Doppler and weather radars are consoled here. Robot video cameras in the data room can be controlled from this room, providing zoom closeups of incoming data, new maps, and other information. And telephone lines link this system with the control room at Cimarron, with key people in the laboratory building, and with the myriad other players in this unfolding drama.

The NOAA van moves out into the afternoon. Another team from the University of Oklahoma is also on the road.

Thus, the observational trap is armed. Aircraft are on alert; as the storms move closer, the control room will scramble the aircraft to take a few hours' data. Instrumentation checks of the Doppler radar have been made and the radars are now ready for comprehensive data gathering, as are surface stations and radiosondes. Now, as people and storms converge, the waiting of days becomes the waiting of hours.

Over dinner, the television meteorologist describes today's tornado watch, the rectangular area where, Kansas City severe storm specialists believe, most of the worst weather will come this evening. Oklahoma City is within the southern border of the box, which runs nearly north and south over part of Oklahoma and central Kansas.

Kansas has already begun to take punishment from the advancing storms—golfball-sized hail in Salina. A funnel west of Lyons. Toward evening, damage to windows, cars, trees near Sterling, where hail to softball size is reported. Around five, the day's first reported tornado rips down power and telephone lines and destroys a farm near Nickerson. Another tornado perhaps an hour later cuts past Hillsboro, flattening some mobile homes east of Hutchinson, and other farm and recreational buildings. At about 7 p.m. the first severe thunderstorm in the observational area brings damaging winds and hail to Enid, Oklahoma while under intense observation by NSSL's array of sensors. By 9:30 the storm has moved beyond Doppler range, the sky is dark, the radars are still and the aircraft have again returned to base. The radios and communications lines are quiet again. Pending study, data sleeps in computer memories, film cans, weather maps, reels of magnetic tape.

However, analysts already have begun the task of sorting data. Laboratory scientists engaged in theoretical studies are working with their models to assess differences and similarities. The real work has just begun.

Sailing ships and satellites explore the secrets of

Waves Beneath The Sea

BY JOAN VANDIVER FRISCH

Satellites, high-flying aircraft and other exotic scientific tools have joined forces with many out-of-the-ordinary allies in their search for new knowledge.

But with a 100-foot schooner which might have sailed straight from the 19th century?

Exactly. Twice last summer the research vessel Westward, sailing between Bermuda and New York, combined its services with those of the most advanced technology to help probe an old, closely-held secret of the sea—internal waves.

The staysail schooner kept a series of North Atlantic rendezvous for the Atlantic Oceanographic and Meteorological Laboratories, with Dr. John R. Apel, Director of AOML's Ocean Remote Sensing Laboratory, as chief scientist on the first voyage and his colleague, Dr. John R. Proni, on the second.

As Westward sailed another, more modern object moved into position for their meeting. The National Aeronautics and Space Administration's first Earth Resources Technology Satellite, ERTS-1, hurtled southward along its 570-mile-high, nearly polar, near circular orbit just east of Bermuda. The satellite drifts westward at a rate of a little less than a degree and a half per day. This brings it over the same point on the earth's surface every eighteen days—and it would bring ERTS-1 over the WESTWARD as she tacked toward New York.

Another NASA vehicle also prepared to keep the meeting: a U-2 aircraft. The high-flying half-jet, half-glider would time its flights to coincide—or nearly coincide—with an ERTS-1 overpass and the track of Westward when she was about 100 miles southwest of New York.

Internal waves and their accompanying surface slicks have long been studied by oceanographers because of their importance in oceanic mixing processes and to the propagation of sound underwater. Scientists also speculate that internal wave formation by lunar and solar tides, their subsequent breaking, and dissipation of energy are important processes in the gradual lengthening of the day over millions of years.

"Previously, friction due to tides moving over the rough ocean bottom was felt to be the cause of this slowing down of the earth's spin," says Dr. Apel. "Since the decrease in the earth's rotation rate requires the constant dissipation of about three million megawatts of power, recent oceanic measurements have cast doubt on the effectiveness of the ocean bottom alone to accomplish this. Instead, internal wave activity has become a second candidate."

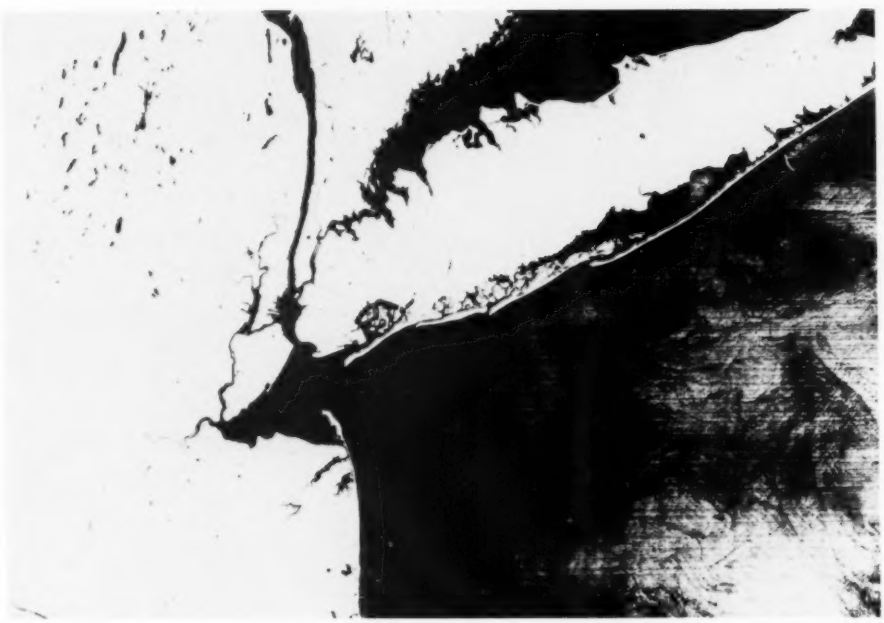
Although no positive proof exists, internal waves have been postulated to be the villain of the declining herring industry in Sweden. From the thirteenth to the fifteenth century, abundant supplies of fish regularly entered the fjords of Sweden and also the Baltic Sea through passageways from the North Sea. According to Swedish scientist Otto Pettersson, the cause for this diminished supply may lie in the internal waves that enter these passageways at approximately tidal intervals. His calculations show that during the times of herring plenty, the lunar and solar tidal forces were at a maximum. During the past five centuries, as part of a long cycle, those tidal forces have dwindled. Pettersson has theorized that the huge internal, tidally induced waves of the thirteenth to the fifteenth centuries swept the herring in front of them into the fjords, while the smaller waves of today are insufficient in amplitude to accomplish the feat.

Internal waves may also be a hazard to submarines. With tanks adjusted to neutral buoyancy on the surface, a submarine will rise and fall with boundary waves. When underway, however, the submerged submarine could move out of a neutrally buoyant water layer and pass through a large wave face into lighter water, causing a sudden dive, which could result in an involuntary descent into increased pressure depth. Oceanographers have conjectured that internal waves may have been involved in the mysterious disappearance of the United States submarine Thresher twelve years ago.

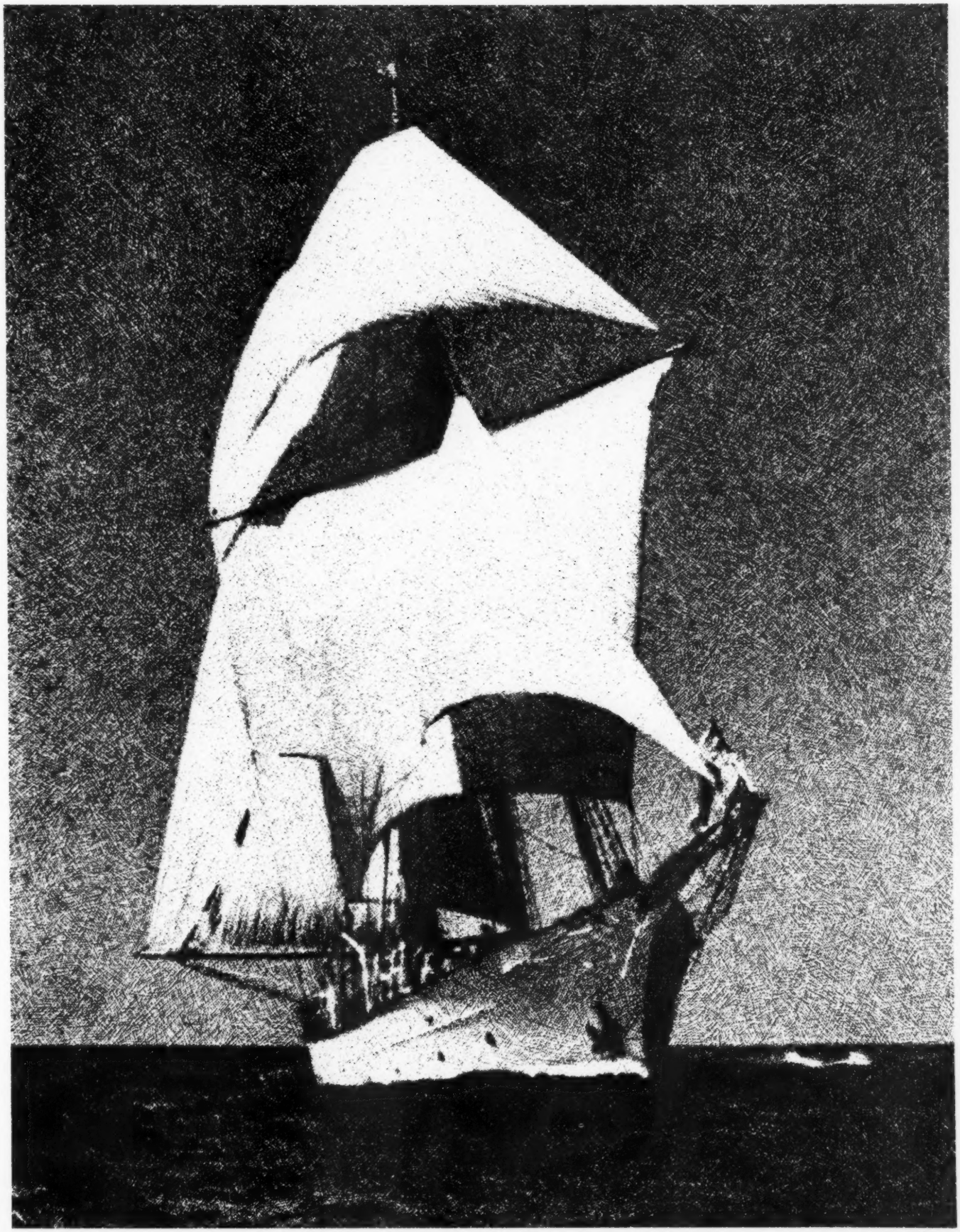
Waves are generally thought of as occurring along the boundary between the water's surface and the atmosphere. But internal waves do not; they are generated under the surface at a boundary between two horizontal layers of water of differing temperature and saltiness.

"Internal waves are probably most familiar to the nonoceanographer through devices sold in novelty stores in which a clear plastic box filled with two liquids of different colors and densities is rocked slowly back and forth," Dr. Apel explains. "The large waves on the border between the liquids travel majestically along the box and crash into the ends to form breakers. The same kinds of waves can be generated in the ocean wherever changes in water temperature or salinity lead to changes in density of sufficient magnitude."

Internal waves differ from their surface wave "relatives" in another significant way.



From a NASA satellite 570 miles above Long Island, N.Y., underwater or "internal" waves are indicated (above) by a half dozen or so striations. Each wave is oriented about parallel to the outer edge of the continental shelf. The research vessel Westward (right) sets sail for a rendezvous 100 miles southwest of New York to assist in the probe to solve the secret of internal waves, believed to have been involved in the mysterious disappearance of the U.S. Navy atomic submarine Thresher which sank in the North Atlantic on in 1963.



(Top left) Westward first mate Jim James assists Dr. Apel in lowering the "batfin" (top right), a scientific instrument used to measure water temperature 150-feet (50 meters) below the surface of the sea.
Oceanographer H. Michael Byrne (lower, left) raises a portable salinity-temperature-depth probe to verify the presence of internal waves. While two apprentices observe (lower, right), Byrne resets the probe's graph mechanism.

On Westward

Under the flag of the Sea Education Association (SEA), the research vessel Westward annually sails 20,000 miles in far-ranging, ocean-related studies. The 220-ton schooner is engaged in several kinds of oceanographic work including regular environmental monitoring of the effects of man upon the ocean. Visiting scientists, such as those from NOAA's Ocean Remote Sensing Laboratory, are frequently aboard the Westward, conducting their own investigations. In addition to the internal wave verification work by the Commerce Department agency scientists, the sailing vessel has been involved in studies of fish distribution in the Cape Verde Islands off the West African coast, the population of nesting sea turtles in the Galapagos Islands off Ecuador's coast, internal temperature regulation in swordfish and whale behavior near Newfoundland.

To carry out her mission, the R/V Westward has a ship's company of up to 28 persons including as many as 20 apprentices from schools, colleges, and post-academic life. Unlike service they might acquire in the air-conditioned environment of mechanical-powered research vessels, the student-apprentices do not practice sophisticated oceanographic techniques. Rather they acquire from direct personal experience of the ship's staff and visiting scientists an understanding of the ocean and man's relationship to it. Drawn from all walks of life and ranging in age from sixteen years upwards, the apprentices provide the manpower to carry out the ship's operational and scientific missions, and are subject to the direction of the ship's officers and scientific staff.

Full academic credit for the apprenticeships is available to those crew members who enroll in the Westward's Sea Semester, designed to increase the nautical and oceanographic literacy of college and post-college students. The program combines six weeks of intensive academic instruction ashore in marine science, nautical science, and man and the sea with a six to seven-week seagoing apprenticeship. Successful completion of the program earns 16 semester credits from Boston University, which are transferable to most other academic institutions.

On-the-job training takes place in the laboratory, engine room, galley, on deck, and ashore. Much of it goes on during night watches. Staff members demonstrate and give practical training in the special skills of seamen and research assistants, designed to equip apprentices for their daily work. Each morning the ship's officers discuss and/or clarify aspects of nautical science.

In the course of a voyage most of the topics described in the sea semester course on nautical science are treated with the emphasis more practical than theoretical. Each afternoon the ship's scientific personnel discuss aspects of marine science which are appropriate to the current operations. Emphasis is upon the practical use of gear, treatment of data, and oceanographic phenomena encountered during the day.

While they are slower than surface waves (because of the small density difference between adjacent liquids) they can be much larger in amplitude—as high as a 20-story building. While the up-and-down motion of the underwater layers may amount to hundreds of feet, very little vertical movement occurs at the water's surface.

But the large horizontal motions beneath the surface affect the very small, wind-caused surface wavelets, changing the way sunlight is reflected and scattered from the parts of the surface overlying the internal waves. This periodic change in reflected sunlight, which travels with and above the underwater wave, appears to be what the NOAA oceanographers have detected on satellite images.

Dr. Apel and a colleague, Robert Charnell, first spotted the striations on the ocean's surface on images made from ERTS–1 over the Atlantic Ocean off New York City, in the vicinity of the Hudson Canyon—the ancient drowned riverbed on the continental shelf through which the Hudson River flowed during the last glacial period.

The waves appeared as several packets, or groups, each composed of a half dozen or so striations. Each wave was oriented about parallel to the outer edge of the continental shelf, spaced approximately one-quarter to one-half mile apart. The separation between packets of waves was usually about six to eight miles.

According to the NOAA oceanographers, the packets were observed to progress farther up the Hudson Canyon, because of the deeper water there, than they did over the shallower water on the adjacent shelf.

Dr. Apel attributes the internal waves to tidal action at the deep-water side of the continental shelf. He believes that, every twelve and a half hours, as the incoming tidal current encounters the sharp change in depth at the edge of the shelf, the right conditions for launching an internal wave packet are set up for a few hours.

Set in motion, this packet, which is concentrated at a depth just below the upper mixed layer of the ocean, travels through the water over the shelf until reaching the sloping bottom, where it breaks much as a surface wave breaks on the beach.

"The several packets seen in some of the ERTS–1 images are probably due to the repetition of this process during several tidal cycles preceding the overpass of the satellite," Dr. Apel explains.

Similar oceanic features have also been detected by images from NASA's Skylab and the Air Force meteorological satellite, over both shelf and deep ocean areas.

"To date we have observed these features off the North American east and west coasts, the Gulf of California, the African east and west coasts, northern South America, the central Pacific, and the Celebes Sea southwest of the Philippines," Dr. Apel says.

It was to verify that the striations seen on the ocean's surface from space were actually surface signs of deep underwater internal waves, that Dr. Apel and his colleagues—Dr. John R. Proni, H. Michael Byrne, NOAA Corps Lt. Ronald L. Sellers, and Charles Lauter—sailed aboard Westward.

The NOAA scientists selected the schooner because they felt one of their new observational instruments, an acoustic echo-sounder, would function much more sensitively in the quiet environment of a sailing vessel. The ship carries a crew of 18 seagoing apprentices who also serve as scientific assistants.

For the experiment, the Westward moved synchronously with several ERTS–1 overpasses during two 18-day periods, while NASA gathered data simultaneously from the satellite. In addition, the U–2, flying at 65,000 feet over the New York City harbor area, between Sandy Hook, New Jersey, and the Hudson River Canyon, tested the Goddard Space Flight Center's coastal zone color scanner in conjunction with the Westward on one other day.

The Miami research team correlated the ERTS, U–2, and surface camera imagery with subsurface measurements of internal waves taken aboard the sailing vessel with thermistors, bathythermographs, acoustic echo soundings, and salinity-temperature-depth probes. The resulting data verified that the surface slicks *did* have underlying internal wave motion associated with them, and that the slicks were the objects being seen by spacecraft and in aircraft photographs.

According to Dr. Apel, the combination of simultaneous spacecraft imagery and shipboard acoustic echo-sounding equipment constitutes a promising new tool for oceanography. The promise is great enough that a second cruise aboard Westward is planned.

This one will begin in early April in San Juan, Puerto Rico, and end at Woods Hole, Massachusetts, about mid-May. The expedition will concentrate on the Anegada Passage—where Westward's course will be coordinated with ERTS–2—and the Gulf Stream—where the schooner will match paths with the GEOS–III spacecraft from the continental shelf off Morehead City, North Carolina, to the longitude of Newfoundland, as Westward, again under NOAA charter, will keep another series of Atlantic rendezvous.

Adventure Comes With the Job

BY JANE E. O'DELL

Describing the duties of a field survey crewman is straightforward enough—find the latitudes and longitudes by making triangulations, find the water depths by making soundings. But describing his job—particularly in the early wilderness days—is quite a different matter. The surveymen who trudged through the wilderness harassed by black flies, enduring spoiling food, watching their fellows desert for an easier post during mid-season, were a hardy breed.

For the Lake Survey, surveying started with a Congressional Act to chart the Great Lakes area, which in 1841 was mostly wilderness. There were small settlements in such places as Cleveland, Detroit and Chicago, and Buffalo was a busy transfer point for westward migration, but for the most part the region was little known except by French-Canadian voyageurs and the Indians. To accomplish the work, the Survey relied upon men who persevered despite frostbiting winters, scorching summers, difficult terrain, shipwrecks, and a host of other hazards.

Although irritations occasionally occurred, the men also formed close friendships with each other and with the sometimes hostile Indians. Captain John W. Gunnison of the Lake Survey formed a strong friendship with the Indian chiefs. His hunting ability and his demeanor made him highly esteemed. Often a chief would eat in Captain Gunnison's camp, discussing with the Captain the survey work and the party's intentions while in their land. The chief would always leave well satisfied and never empty-handed, taking with him tobacco and hard bread.

In 1853 Captain Gunnison was making a survey for a Pacific Railway route. An indefatigable worker, he went ahead of the troops guarding him and his party. Gunnison was not afraid, since he had worked on the Great Lakes and established good relationships with the Indians. But one morning he heard a great outcry, as Indians attacked his camp. Running from his tent, he begged the Indians to desist, since he was their proven friend and a close personal friend of their chief. His pleas fell on deaf ears, and he was slain. It was revenge for an Indian apparently murdered by another group of white men who had recently crossed the area.

When the chief found that his friend had been slain, he was inconsolable. Indian legend and lore called for removing a close friend's or relative's right hand and preserving it. So, to honor and mourn his good friend, he cut off Gunnison's hand, dried it and hung it in his tepee as a sacred relic.

Sometimes wild animals were not as perilous to man working in the woods as man was a hazard to the animals. After months of stored and half-spoiling food, bear meat was considered a delicacy and bear hunting was an entertaining enterprise. In those early days survey crews were given money to buy bread and vegetables from farmer's wives, but had to hunt for the meat they needed. The Records show that in 1873 three black bears were spotted by a field party. Immediately, a bear hunt was organized. The men, armed with butcher knives, hatchets and revolvers, readied themselves for the chase. They zeroed in on one bear. Shots were fired. They missed. The bears escaped unharmed. This particular example of marksmanship has gone down in the annals of the Center as giving rise to wonder that surveyors didn't die of starvation.

Travel by ships in the early days was full of hazards. Ships would go aground, they would crash on uncharted shoals, or they would simply vanish. In particular, many ships that started from Lake Superior ports were never seen again—a sort of Bermuda Triangle of the Great Lakes. The steamers Inkerman, Cerisoler and Bentzen, built for France as minesweepers, sailed from Fort Williams, Ontario (now known as Thunder Bay City), on October 24, 1918. The weather was stormy over their route from Fort Williams past the northern side of Isle Royale, southeasterly toward Whitefish Bay to the Soo locks. Leaving port at different times, they sailed out into the foreboding, churning waters. The Captains of the Inkerman and the Cerisoler, experienced ocean sailors, had reportedly laughed at Lake Superior as a "pond." But they underrated this powerful, sometimes treacherous inland sea. The two ships disappeared with 70 men, and neither bodies nor wreckage were ever found.

The Bentzen was on time at the Soo, weathering out the storm. The Armistice came before she could see duty overseas, however, so—since she had been built with American funds—she became the property of the United States, and eventually became the Lake Survey vessel, Peary.

A partial answer to some of the unexplained "mystery disappearances" in Lake Superior's deep waters may have been found when, in August 1929, the steamer Margaret discovered Superior Shoal quite by accident during one of her first deep-sea sounding efforts. Superior's waters had been sounded and surveyed many times without revealing a clue as to the existence of the infamous shoal. But earlier sounding lines were usually far apart, and the shoals in the "big lake" generally have quite small surface areas. Imagine a 1,000-foot pinnacle of mountain rising from the bottom of the lake, its point hidden only a few fathoms below the surface. This describes Superior Shoal precisely.

On the discovery survey, deep-sea soundings were being run northeasterly toward the Canadian shores. They were taken on perpendicular angles from a line of buoys located near Manitou Island across Lake Superior waters to near Isle Royale. Lake Superior was foggy. Depths were being recorded in the 600 to 900-foot range. Suddenly the electronic depth-finder recorder dial jumped erratically for just a second, then indicated deep water again. The crew could not believe what they had seen. After a lively discussion, the ship was turned about and the soundings rerun. Again the dial jumped, exactly as before. Subsequent courses from the Canadian shore to the buoy lines verified, without a doubt, the existence of the shoal. The least depth over its tip was determined to be 21 feet.

Twenty-one feet is ordinarily a safe depth for most vessels plying the lake. But storms on Lake Superior are noted for their fury. Huge waves lift ships high above their normal level, from which they crash down into abysmally low troughs, where their hulls might collide with submerged but upthrusting peaks. And wooden or even steel-hulled ships are no match for jagged rocks. The shoal was directly on the recommended course-line, the course followed not only by the two ill-fated minesweeper sister ships of the Peary, but by most other vessels as well. How many ships lie on the bottom around the base of Superior Shoal? No one really knows, but its discovery by Lake Survey doubtless has saved many others from ending up as "mystery losses", claimed by an unseen peril lurking in the deep and otherwise safe waters.

The unexpected does not always bring disaster—sometimes only chagrin. Two technicians were inspecting a water level gage station at Harbor Beach, Michigan, one cold, windy fall day in 1968. One of them, on his first inspection trip, sought sanctuary from the weather inside the gage house where the other technician was examining the gage. These houses are small, resembling nothing so much as large outhouses, and they are always kept locked as protection against vandalism. As the technician shut the door behind him, he noticed the inside knob of this snug little house was loose. It turned ineffectively around and around in its socket. "Don't shut the door," shouted the other technician. "I just did," came the reply.

With all the keys in his pocket, and two weeks more before they were expected back

"Loaded for bear", in the early days of the Lake Survey, was more than a catch-phrase. Crews, like the one above, had to shoot the meat they ate, and one popular way to find their meat rations was to go bear hunting. For these hardy pioneers a day in the woods not only provided a meal for the table, but it was an excellent source of entertainment as well. An 1873 bear hunt was not successful when the surveyors were armed with butcher knives, hatchets and revolvers. The bears escaped unscathed, according to the record.

at the Center, he had no hope for rescue. Even if they could attract the attention of a passing stranger, there was no way they could get a key outside to him. However, with the persistence—if not the skill—of master thieves, they finally forced the knob to work, releasing them from their unique prison. It was some time before the details of this adventure surfaced, and the two red-faced technicians finally admitted that yes, they had indeed locked themselves in the gage house.

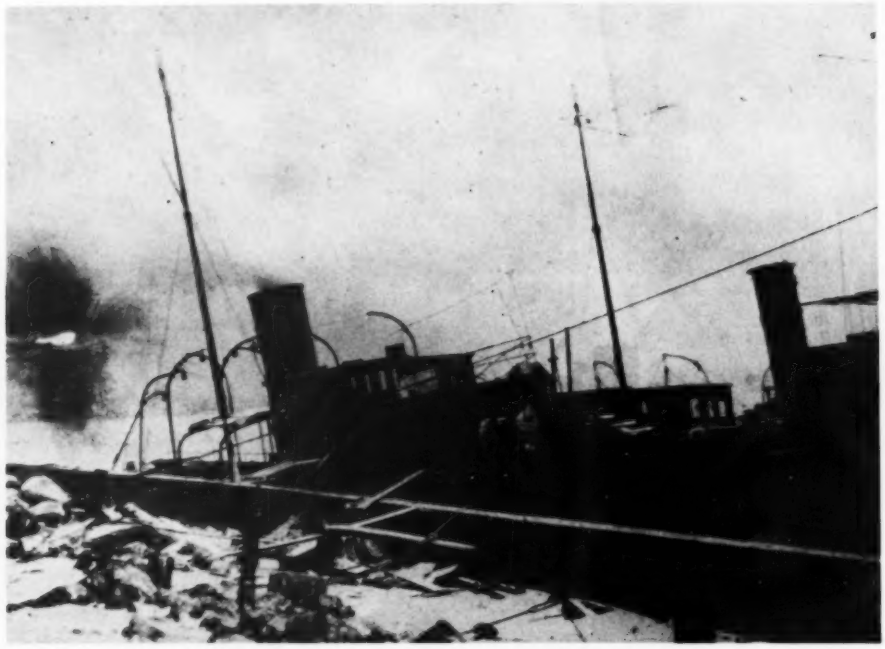
William H. S. Hearding was one of the earliest civilian engineers to work for Lake Survey. An Englishman by birth, he had traveled extensively around the world before enthusiastically, if naively, joining a rugged Great Lakes survey team. The party's mission during Hearding's first trip in 1851 was to make a general hydrographic survey of "Les Cheneaux," a group of islands located in northern Lake Huron, which at that time was a lonely and isolated part of the Great Lakes. The party included the Chief Officer and four assistants, of which Hearding was one, and thirty-five men, mostly experienced French Canadian voyageurs. It was the first official U.S. survey of these waters.

Detroit was sweltering when they left by steamer in early May. The trip through the Detroit River and Lake Huron, to near the Straits of Mackinac should have been uneventful. However, the sultry weather remained with them. "Watch out for bad weather, Hearding, Thunder Bay (in northern Lake Huron) is deadly this time of year," warned a now-forgotten sailor in Detroit. Young and an inexperienced lake traveler, Hearding watched the skies. Apprehension mounting as the ship approached the Bay, he sighted ominous dark clouds growing quickly in the northern skies. Shortly the ship was engulfed in violent, tumultuous waves. The sky turned black, though sunset was hours away. The creaking and groaning of the ship's timbers under the board guards reminded Hearding of a witches' dance. Clinging to their beds and fearing for their lives, the terrorized men passed a sleepless night.

By morning the storm had passed, the vessel had proved seaworthy, and the passengers, slightly the worse for wear, had begun to recover. They all arrived safely in the islands the next day. Hearding never again received such a warning and he never again experienced a storm of that magnitude while at sea, though he sailed the lakes for many years after his initial baptism. But he never forgot that first trip.

One July morning in 1969 outside Buffalo, New York, two engineers arrived at the Black Rock Canal where they were to run levels to the water level gages there. After parking their truck, they noticed several former Lake Survey Center employees, who were now working for the Detroit District, Corps of Engineers. The Corps men were measuring river flows in the area. The Corps crew said, "Come on" to the Lake Survey technicians—"We'll buy your coffee." One of the engineers said later that he should have known when they offered to buy coffee that something was wrong. But they accepted anyway.

After finishing their work on the gage site, the two went back to their truck. The Corps personnel working on their project close by stopped work to watch. As they started the truck, whistling sounds and a profusion of black smoke suddenly bellowed out from the truck's front end. One technician jumped out one side of the truck, the other jumped down from the opposite side. Both came to the front. The first grabbed a fire extinguisher; the other reached for the hood. As soon as the hood was slightly open all was clarified by the grin on the face of one of the Corps surveyors. It was a smoke bomb and an elaborate hoax. The lesson, they concluded, was to refuse free coffee when offered by old friends whose reputations don't include being loose with a buck.



(Left above) Water level gage houses on the Great Lakes have had their share of adventures. (Above) Survey Steamer "Margaret" lies wrecked at a dock in Fort Wayne Boat-yard. (Right) These are the jagged peaks of Superior Shoals in Lake Superior, a likely answer to the mysterious disappearance of many ships lost in the Lake's deep waters. The Margaret herself sank during a violent storm on Lake Michigan on November 1, 1926.

Nature has always been a source of amazement to those working on the Great Lakes. Hearding's appreciation was unequaled when he first saw the virgin forests and lands in 1851 in "Les Cheneaux." The vast evergreen forest, dewdrops sparkling in the sunlight, and the purity of the atmosphere were more than captivating. It left an impression that would last him a lifetime.

However, there were other nature-loving episodes that Hearding found less enjoyable. His tent-mate collected botany specimens with great zeal. Since the woods proliferated in moss and fungus production, the tent became "a depot for the storage of many wonderful specimens," evidencing a true and astonishing cross-section of these interesting natural phenomena. Being a patient man, Hearding waited. There had to be an end to the different varieties. But the collection continued to grow and the disorder and odor continued to grow also. Finally, when the "vegetation became of such magnitude and character to no longer be tolerable," Hearding took action. With the help of another, he transferred the collection from the tent to an outside area nearby where it remained unchallenged for the trip's duration. Without words, the eager botanist obviously got Hearding's message.

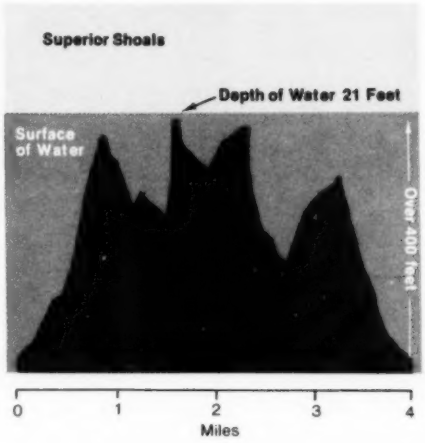
Some Lake Survey vessels, not as seaworthy as Hearding's, had great problems with storms. The Survey Steamer Margaret ran into a full gale on the first day of November in 1926. She and her crew had spent a quiet day taking soundings off Port Crescent, Michigan, along the northeastern coastline of Lake Michigan. The weather was calm and the water quiescent. After the day's activities, the crew secured the Margaret to a sturdy pier in the harbor and went ashore for their well-earned dinner and rest.

Then, about 9:30 that evening, the winds rose rapidly, and their howling was accompanied by a driving, cold rain. All hands raced back to the harbor to check on their ship. She must be moved or be dashed to pieces.

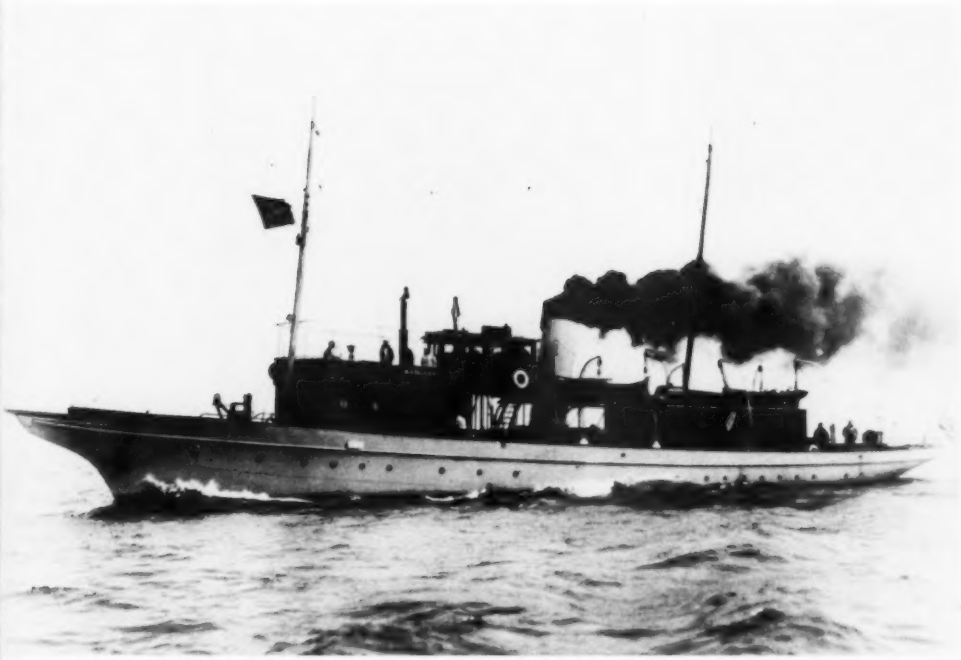
Underway to try to ride out the storm, and with waves washing over the pilot house, the helmsman tried to steady her on a course to seaward. With the winds at a recorded 80 miles per hour, the wooden topside cabins began breaking apart, so the crew decided to attempt to bring her back near the dock again. When she began listing badly and steering became impossible, all hands jumped off and struggled to safety, where they sadly watched as she disappeared beneath the violent white water. Miraculously, no lives were lost.

The Margaret later was raised, repaired and sailed again, so her defeat by the elements was only temporary.

Sometimes, in cases of emergency, Survey personnel have accomplished more than mere survival. In 1917 engineering support was requested from Lake Survey personnel to measure distances for airplane races, on a triangular course between Selfridge Air Force Base in Mt. Clemens, Michigan, Packard Air Field near Detroit, and Gaulker Point on Lake St. Clair. Two survey aides were assigned the task, in which they would discuss their measurements with General William "Billy" Mitchell, an early advocate of air power. At this time, he was visiting Selfridge with the then Secretary of Commerce Herbert Hoover.



The aides picked up their survey equipment, boarded the electric line, Detroit United Railway, and traveled to Mt. Clemens and then over to Selfridge. The necessary triangulations for measuring the distances between the points were made. Everything was set. The trials were on. The two aides, atop a pylon at Selfridge with their theodolite, which measures horizontal and vertical angles, watched the planes roar past the finish line. Then, while still in the air, one plane's undercarriage ripped off. It belly-landed, flipped over, 40 feet from where the surveymen were stationed. Rushing from their stand, without thought, except that they were closest, the men ran to the damaged plane and pried open the crushed fuselage. Carefully, they lifted the unconscious pilot from the plane. His mouth was cut from ear to ear, and filled with



The treacherous 1,000-foot pinnacle of Lake Superior's Superior Shoals was first found by Lake Survey Steamer "Margaret" (above), which after sinking was raised, repaired, and sailed again on the Great Lakes.

clogging blood and gasoline from the ruptured tank. The aides gently cleared the pilot's tongue, draining as much gasoline and blood from his mouth as possible. Finally, the ambulance crew arrived. It was after the aides had stepped aside that they began to think clearly and wondered why the highly volatile gasoline had failed to explode. Fortunately for all, it did not, and they saved the pilot's life that day.

On other occasions danger leads to nothing worse than drollery. Last year, at Hammond, Indiana, one of Lake Survey's launches began running poorly. Repair would require a hoist, so the boat could be pulled out of the water, and the nearest hoist was about 10 miles away. To reach it, the boat would have to travel around the Port of Indiana, which has a long breakwater stretching well out into Lake Michigan. One of the crew volunteered to take the boat and confidently started the trip. However, a high wind was blowing, and the lake was rough, with waves three to four feet high. Shortly, he realized the boat was failing badly; trying to round the breakwater would be foolhardy. So he turned the boat to head for a closer marina, when the ailing motor coughed twice and died.

The winds and waves, which previously had hindered progress, now gently but firmly pushed the boat into the shelter of a plush private yacht club. The crewman's problems were not yet over—a haughty lady member questioned his right to be there. After carefully and patiently explaining the situation to her at some length, he was permitted to remain. The U.S. Coast Guard was called, and they, in turn, notified the local police department, which sent their boat to help. The surveyor reported that "They threw me a line and told me to tie a knot, so they could tow the boat. When I started to tie the knot, they hollered, 'No! It has to be a bowline!' " By that time, after hours of worry, the surveyor shouted (untruthfully), "I don't know how to tie a bowline." The policeman—who later became a friend and even helped repair the vessel,—replied, "What are you doing out on the water, then?" To which the frustrated crewman rejoined: "I'm a surveyor, not a Boy Scout."

In the old days, falling trees were a common hazard. Trees were felled while setting up a survey camp, as well as for clearing a line-of-sight during surveys. Forests were thick, and trees grew close together. Hearding claims, "the warning of 'stand from under' which ought always to be given a minute or two before a tree falls is somewhat carelessly omitted by the axemen until the tree is actually toppling." Those standing close to the tree make a quick rush to safety.

In 1870 Captain Jared A. Smith, who was an officer in the Corps of Engineers, and his crew were working near Bayfield, Wisconsin, on Lake Superior's westerly shore. In a letter to his superior, General C. B. Comstock, Smith explains what happened. "I went Westward and anchored the Steamer Surveyor near the position for next triangle Wednesday morning. I went with the crew nearly a mile from shore and in order to make the triangle as small as possible commenced cutting out the lines before constructing the station. At 2:00 p.m. while two men were cutting a tree against which another had lodged, the jarring caused the lodged tree to fall with such suddenness that there was no time for escape and Joseph Bertram was struck in such a manner as to break many of the bones of the skull—besides many other severe injuries. He was unconscious from the moment and died at 9:20 p.m. same day. I made a litter with the means at hand, and had him removed to the Steamer as soon as possible, and immediately started for medical assistance. He died 10 minutes before we came to anchor in Bayfield. I had a box made and the body was packed in ice and forwarded to the family and friends in Detroit per Steamer Northern Light. As the man was struck down while hard at work in the government service, I have presumed the expenses incurred would be paid by the government. I do not know what the freight on Steamer ought to be, but the other expenses are trifling as the boat's carpenter assisted in making the packing box.

"Since this unfortunate occurrence the men have seemed paralyzed, and they are so extremely superstitious that it was with difficulty they could be induced to move the box containing the dead body. Yesterday, two men left the Steamer Surveyor, one the leadsman (the only one on board) and the other a wheelsman. They could not be induced by either persuasion or threats to remain. This leaves me in addition to other disadvantages which I stated to you verbally—with two wheelsmen only, and one of them is only about, after having been very low with fever, and able only for very light duty for short intervals. The other wheelsman is blind in one eye and at times is subject to turns resembling partial insanity and at these times is entirely unfit for this duty." Smith apologized to General Comstock for not having accomplished more definite results. The original of his letter, in Lake Survey Center's files, is mute testimony of the trials and tribulations faced by early surveyors.

Each year the saga continues. The surveyman is still away from his loved ones for most of the summer. Though no longer armed with a shotgun for providing his own meat, he must often stay in substandard motels and rooming houses. Ships with diesel engines have replaced the early coalburning vessels; and the latest electronic and scientific instruments have replaced his primitive, often makeshift, measuring equipment, and now his radio keeps him in constant contact with others, making life today just a little easier. Still the spirit of adventure remains. Each season the men come back with tales of new experiences—like the time not long ago when the Safety Officer, eager to get action pictures of his crew performing in their life-jackets, shoved himself off in a rowboat and forgot the oars, necessitating his own rescue—or the rescue from a small capsized sailboat of a young couple (married, but not to each other)—or the Surveyman who fell through the ice during a winter operation, but managed to keep a valuable government camera high and dry. Names change, situations differ, but today's Lake Survey field personnel display the same love of adventure and dedication as did their long-gone predecessors.

Sea Fare

Seafood For Slimness

After a sedentary winter, many a citizen greets spring with the firm resolve to lose a few pounds. But the need to count calories to show results causes all too many diet resolutions to fall by the wayside all too soon. The National Fisheries Education Center suggests, to those whose resolve has weakened, that it's time to take a good look at the wonderful world of seafood! Versatile fish and shellfish really shine when it comes to providing low-calorie, high nourishment food.

In addition to the valuable protein and other necessary nutrients for the whole family, the same seafood entree is usually just right for dieters and non-dieters alike. Fish fillets are appropriate for any entree because there is no waste, just 100 percent good eating. One of the most popular varieties of fish fillets are those cut from flounder or sole, and these species are interchangeable in most recipes.

Crabmeat Cornucopia

1 pound crabmeat, fresh, frozen, or pasteurized or
2 cans (6½ or 7½ ounces each) crabmeat
½ cup salad dressing or mayonnaise
2 teaspoons sugar
1 tablespoon lemon juice
4 teaspoons grated orange rind
1 cup thinly sliced celery
1 cup orange section halves, well drained
½ cup sliced pitted ripe olives
2 tablespoons sliced green onion
Crisp salad greens
6 avocado halves, or 6 1-inch slices of peeled cantaloupe, or grapefruit or orange baskets (optional)

Thaw frozen crabmeat. Drain crabmeat well. Remove any remaining shell or cartilage. Mix salad dressing or mayonnaise, sugar, lemon juice, and orange rind. Combine well-chilled crabmeat, celery, oranges, olives, and onions. Add salad dressing mixture; toss lightly. Serve on crisp salad greens, plain or in avocado halves, center of melon slices, or orange or grapefruit baskets. Makes 5 cups salad mixture, about 6 servings.

Sea Slaw

- 1½ pounds fish fillets, fresh or frozen
- 1 quart boiling water
- 1 tablespoon salt
- ¼ cup low calorie salad dressing (mayonnaise type)
- 2 tablespoons chopped onion
- 2 tablespoons sweet pickle relish
- 1 tablespoon lemon juice
- 1 teaspoon salt
- 1 cup shredded green cabbage
- 1 cup thinly sliced celery
- 6 lettuce cups
- Lemon wedges

Thaw frozen fillets. Place fillets in boiling salted water. Cover and simmer about 10 minutes or until fish flakes easily when tested with a fork. Drain. Remove skin and bones; flake. Combine salad dressing, onion, relish, lemon juice, salt, and fish. Chill at least 1 hour to blend flavors. Add cabbage and celery; toss lightly. Serve in lettuce cups. Serve with lemon wedges. Makes 6 servings.

(Approximately 120 calories in each serving.)

Tuna Danish

- 2 cans (6 ½ or 7 ounces each) dietetic tuna
- 1 cup coarsely grated cabbage
- ⅔ cup coarsely grated carrot
- 3 tablespoons low calorie salad dressing (mayonnaise type)
- 1 tablespoon catsup
- 1 tablespoon lemon juice
- ½ teaspoon salt
- Dash pepper
- 6 lettuce leaves
- 6 slices low calorie bread, toasted
- 18 cucumber slices

Drain and flake tuna. Combine cabbage, carrot, and tuna. Combine salad dressing, catsup, lemon juice, salt, and pepper. Add to tuna mixture and blend thoroughly. Place lettuce on toast. Place approximately ⅓ cup tuna salad on each lettuce leaf. Arrange 3 cucumber slices diagonally across each sandwich. Makes 6 servings. (Approximately 180 calories per serving.)

Flounder and Broccoli Rolls

- 2 pounds flounder or sole fillets, fresh or frozen
- 2 packages (10 ounce each) frozen broccoli spears, cooked and drained
- 1 teaspoon salt
- ¼ cup dry white wine
- 2 tablespoons butter or margarine
- 2 tablespoons sliced green onion
- 1 tablespoon lemon juice
- ½ bay leaf
- Pimiento strips (optional)

Thaw fish if frozen. Divide fillets and broccoli spears into 6 equal portions. Sprinkle fillets with ½ teaspoon salt. For each roll, wrap a portion of fish around a portion of broccoli spears. Place rolls in large skillet. Sprinkle with remaining salt. Combine wine, butter or margarine, onion, lemon juice, and bay leaf; bring to boil. Pour over fish rolls; cover. Cook slowly for 12 to 15 minutes or until fish flakes easily when tested with a fork. Garnish rolls with pimiento strips, if desired. Makes 6 servings.

Crabmeat Foo Yong

1 package (6 ounce) frozen snow or king crabmeat
1 can (1 pound) bean sprouts, drained
1 can (4 ounce) mushroom stems and pieces, drained
½ cup finely chopped celery
¼ cup finely chopped onion
½ teaspoon salt
Dash pepper
4 eggs, beaten slightly
Foo Yong Sauce (recipe follows)

Thaw crabmeat and remove any remaining cartilage. Chop fine. Combine crabmeat, bean sprouts, mushrooms, celery, onion, salt, and pepper. Add eggs; mix well. Pour ⅓ cup crabmeat mixture onto hot lightly greased griddle or skillet. Fry at moderate heat 2 to 3 minutes or until brown on underside. Turn carefully and fry 2 to 3 minutes longer or until underside is brown. Drain on absorbent paper. Serve with sauce. Makes 6 servings, 2 cakes per serving.

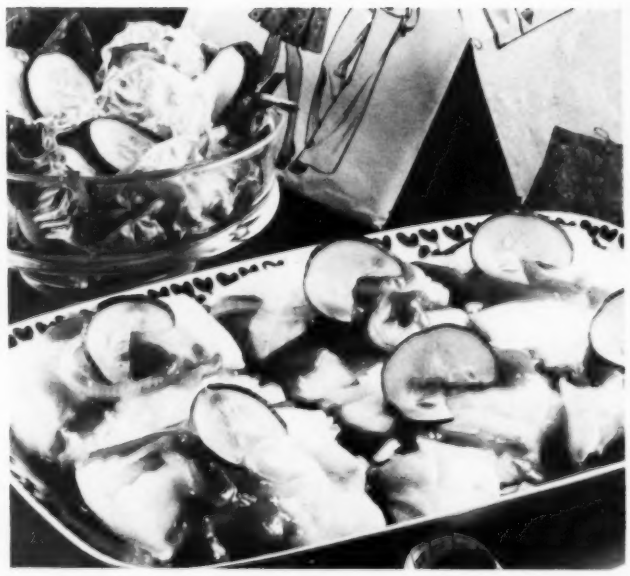
Foo Yong Sauce
2 tablespoons soy sauce
2 tablespoons cornstarch
½ teaspoon sugar
1 chicken bouillon cube, crumbled
2 cups boiling water.

Combine soy sauce, constarch, sugar, and bouillon cube; mix well. Add water and cook, stirring constantly, until sauce is thickened and clear. Makes about 2 cups sauce.

Cod in Tomato-Onion Sauce

2 pounds cod or other fish fillets, fresh or frozen
1 can (8 ounce) tomato sauce
1 cup sliced onion
2 tablespoons lemon juice
½ teaspoon oregano
½ teaspoon sugar
1 chicken bouillon cube, crumbled
½ teaspoon salt
Fresh cucumber, sliced (optional)

Thaw fish if frozen. Combine tomato sauce, onion, lemon juice, oregano, sugar, and bouillon cube in saucepan. Bring to simmering stage. Cover and cook over low heat 15 minutes or until onion is tender. Spoon ⅓ of the sauce over bottom of shallow 2-quart baking dish. Cut fish into 6 equal portions. Arrange fish on sauce in baking dish. Sprinkle with salt. Spoon remaining sauce over fillets. Bake in moderate oven, 350° F., for 25 to 30 minutes or until fish flakes easily when tested with a fork. Garnish with thin cucumber slices, if desired. Makes 6 servings.



Hot Spiced Shrimp

2 pounds raw shrimp, fresh or frozen
¾ cup water
1 tablespoon lemon juice
1 tablespoon mixed pickling spice
1 small slice onion
¼ teaspoon salt
Chopped parsley
Lemon or lime wedge

Thaw frozen shrimp. Remove shells and devein shrimp. Combine water, lemon juice, spice, onion, and salt in saucepan; bring to a boil and simmer 10 minutes. Add shrimp; cover and cook 5 minutes or until shrimp are tender. Drain. Sprinkle with chopped parsley. Serve in shells or ramekins with lemon or lime wedge. Makes 6 servings.

Tuna Salad for Slimmers

2 cans (6½ or 7 ounce each) tuna
2 cups thin, bias-sliced celery
½ cup chopped green pepper
¼ cup sliced green onion
¼ cup diet or regular salad dressing
2 tablespoons catsup
2 tablespoons lemon juice
1 teaspoon prepared horseradish
¼ teaspoon salt
Dash pepper
Crisp salad greens
Cherry tomatoes or tomato slices or wedges
Low-calorie toast or crackers

Drain and flake tuna. Combine celery, green pepper, onion, salad dressing, catsup, lemon juice, horseradish, salt, and pepper; mix well. Fold in tuna; chill well. Serve on crisp salad greens in tomato shells, or with cherry tomatoes or tomato slices or wedges. Serve with low-calorie toast or crackers. Makes 6 servings.

Deviled Crabmeat

2 cans (7 to 7½ ounce each) or 2 packages (6-ounce each) snow or other crabmeat, fresh or frozen
½ cup diced or chopped celery
¼ cup chopped onion
1 tablespoon margarine or cooking oil
1 tablespoon flour
1 teaspoon dry mustard
½ teaspoon salt
½ cup skimmed milk
1 can (4 ounce) mushroom stems and pieces, undrained
1 tablespoon lemon juice
1 teaspoon Worcestershire sauce
3 or 4 drops hot pepper sauce
1 egg, beaten
Paprika or chopped parsley

Drain canned crabmeat or thaw frozen crabmeat and remove any remaining cartilage. Cook celery and onion in margarine or cooking oil until tender. Stir in flour, dry mustard, and salt. Add milk and mushrooms with liquid; cook, stirring constantly, until thickened. Add lemon juice, Worcestershire and pepper sauces. Stir a small amount of sauce into egg. Add remaining sauce. Add crabmeat; mix well. Spoon into 6 greased individual shells or 6-ounce custard cups. Bake in moderate oven, 350° F., for 20 to 25 minutes or until hot. Sprinkle with paprika or chopped parsley. Makes 6 servings.

California Tuna Salad

2 cans (6½ or 7 ounces each) tuna
2 cups orange sections (approx. 2 medium-sized oranges)
1 avocado
1 tablespoon lemon juice
1 cup chopped celery
½ cup toasted blanched slivered almonds
1½ teaspoons curry powder (optional)
½ cup mayonnaise or salad dressing
Salad greens

Drain tuna. Break into large pieces. Reserve 12 orange sections for garnish; cut remaining sections in half. Cut avocado in half lengthwise and remove seed. Peel and slice avocado; sprinkle with lemon juice to prevent discoloration. Reserve 6 slices avocado for garnish; cut remaining slices in fourths. Combine orange, avocado, celery, almonds, and tuna. Combine curry powder and mayonnaise. Pour over tuna mixture and blend lightly. Chill. Serve on salad greens. Garnish with orange sections and avocado slices. Makes 6 servings. (Note: Additional fruits such as pineapple chunks and strawberries may be served, if desired.)

noaa/update

HOME ALERT JOB TO NOAA RADIO

A radio system operated by NOAA has been chosen by the White House Office of Telecommunications Policy as the chief means of getting warnings of natural disaster or nuclear attack directly into homes.

The directive designated the NOAA Weather Radio System—which is operated by the National Weather Service—as the sole Government-operated radio system for communicating such warnings. This means that other systems under consideration or experimentation by the Federal Government "should no longer be considered candidates for this function," said John M. Eger, Acting Director of the Office of Telecommunications Policy.

The announcement is an outgrowth of a November 1971 White House policy decision calling for development of a home warning system in which acquisition and use of home warning receivers is a completely voluntary decision on the part of each citizen.

Said Mr. Eger, "Studies conducted since 1971 now have led OTP to update and reaffirm that policy." He added that the public interest will be served best by a single Government-operated system for warning citizens in their homes and that the NOAA Weather Radio System, which is already operational at some locations, can be easily adjusted to include attack warnings. The NOAA System incorporates a special tone alert signal permitting home radio receivers to be activated automatically if desired by the owner.

In the event of a threatened nuclear attack, the NOAA Weather Radio will provide a supplementary service to the existing Emergency Broadcasting System.

There Is Gold In Seaweed? Sea Grant Does See Hope

A two-acre "farm" growing a common red seaweed found in the Florida keys would be a paying proposition, says a biologist at the University of South Florida in Tampa.

Working under a NOAA Sea Grant, Dr. Clinton J. Dawes calculates that intensive tank culture of the Florida seaweed called *Eucheuma*—which is much in demand for commercial extracts—would yield up to $9.72 per square meter per year.

A "farm" of seaweed-growing tanks taking up a little over two acres of land (about the size of three football fields) would thus be expected to bring the growers a gross of about $85,000 a year.

The three-year study points out that harvesting the red algae under field-grown conditions would yield only about 16 cents per square meter, meaning that more than 12 acres of area would be required to yield around $8,000 annually.

The 60-fold increase in gross revenue by tank culture will have to be considered in the light of such costs as tank construction, water movement, and termperature control," Dr. Dawes notes. "However, based on our study of the ecology, biochemistry, and economics of the plant, mariculture seems feasible and desirable."

Dr. Dawes proposed the use of plastic or fiberglass-coated plywood containers with about three square meters of surface area and using compressed air for water circulation. In a tank of this size about 20 kilograms (44 lbs.) of plant material could be allowed to cycle for about 30 days, increasing in size to about 36.2 kilograms (almost 80 lbs.). This would reduce in dry weight, to about 7.24 kg (almost 16 lbs.). Ten such harvests could be carried out each year in each tank using plants collected from the wild or grown under controlled conditions.

MESA PROGRAM OFFICE TO ERL IN BOULDER

A program to investigate how man has affected the marine environment has been established at the Environmental Research Laboratories in Boulder, Colo.

Charles G. Gunnerson, a sanitary engineer specializing in pollution control in the oceans and estuaries, and in disposal, reclamation, and recycling of wastes, has been appointed Director of the Marine Ecosystems Analysis (MESA) program, and Dr. Edward G. Altouney, a civil engineer-economist experienced in public works and water resources, is the Deputy Director.

The program was formerly attached to NOAA's Rockville, Md., headquarters, and was directed by Dr. Allan Hirsch, who is now with the Interior Department's Fish and Wildlife Service.

Mr. Gunnerson was formerly Director of the Great Lakes Regional Office of the International Joint Commission.

Dr. Altouney was Senior Specialist in Engineering and Public Works for the Congressional Research Service of the Library of Congress. Previously, he was staff assistant to the Assistant Secretary of the Interior for Water and Power Resources.

Lake Survey Functions Reorganized

Various functions and facilities at the National Ocean Survey's Lake Survey Center in Detroit, Mich., have been reorganized as a result of the transfer of functions to the Environmental Research Laboratories in Ann Arbor, Mich., the Washington, D.C., area, and the National Weather Service's Central Region.

The reorganization includes the transfer of operations involving the compilation, reproduction and distribution of Great Lakes nautical charts to the Washington, D.C., area, where the bulk of NOAA's 54 million nautical and aeronautical charts are produced, printed and distributed.

The Facilities Division (renamed the Engineering Division) has been moved to Monroe, Mich., where a NOAA marine base has been developed to handle ship and logistic work for the three vessels which conduct hydrographic and research activities for the LSC and the Great Lakes Environmental Research Laboratory in Ann Arbor.

In addition, part of the Lake Survey's Computer Services Division and a portion of the Lake Survey Library have been transferred to GLERL, which will form part of a projected NOAA Great Lakes Regional Center.

Remaining in Detroit are the Lake Survey's Marine Mapping and Charting Service (renamed the Charting Operatings Division).

AOML divers locate wrecked plane in which four persons died/100 feet under surface of Atlantic. The small plane was winched to the surface by the NOAA Ship Virginia Key.

noaa/update

Smog! Found To Be Killer of Urban Sunshine

Smog, the familiar variety caused principally by auto emissions, does more than sting the eyes and dirty the air over large metropolitan areas. It also decreases the amount of sunshine received by both urban residents and their rural neighbors, according to a study conducted by the Environmental Protection Agency, Coordinating Research Council, California Air Resources Board, and NOAA.

Two scientists on assignment to the Environmental Protection Agency from the Environmental Research Laboratories made a series of sensitive solar radiation measurements at six sites in the greater Los Angeles, Calif., area during the autumn of 1973 and added them to data gathered previously from two locations in the St. Louis, Mo., region.

Preliminary results indicate that smog-ridden urban areas received as much as 35 percent less ultraviolet sunshine than nearby rural areas. The difference between urban and rural pollution concentrations and amount of sunshine received was much greater in the Los Angeles area than was observed at St. Louis.

Dr. James T. Peterson and Edwin C. Flowers, ERL meteorologists assigned to the EPA's Meteorological Laboratory near Durham, N.C., report that in Los Angeles during September and October 1973, during typically high, but not extreme pollution concentrations, the amount of ultraviolet sunlight reaching the top of the pollution layer was reduced by about 25 to 35 percent by the time it penetrated to the ground. In contrast, over a 28-day summer period in 1972, St. Louis pollution screened out an average of only about six to seven percent of the ultraviolet energy.

"While ultraviolet radiation comprises only a very small proportion of the total solar radiation, it's extremely important, both biologically and chemically," Dr. Peterson says. "Ultraviolet energy produces vitamin D in the human body and is also responsible for tanning of the skin. In addition, it is a necessary ingredient for the formation of photochemical smog."

The UV measurement program was part of a larger photochemical pollution field experiment by the Los Angeles Reactive Pollution Project (LARPP) whose purpose is to measure smog concentrations and meteorological conditions, which can then be used for development and validation of mathematical models of photochemical smog.

The NOAA-EPA research team also found that pollution concentrations throughout the Los Angeles Basin varied in location and time of day. Both the atmospheric turbidity and ultraviolet radiation data showed marked diurnal, day-to-day and weekday-weekend variations corresponding to the photochemical pollution cycle.

NOAA, FDA Agree on Inspection

NOAA has reached agreement with the Food and Drug Administration concerning the inspection and standardization of fishery products processed in the United States.

The agreement defines the working arrangements which will enable each agency to administer more effectively its responsibilities relating to inspection and standardization of fishery products. Some of the areas for cooperative action identified in the agreement include joint consultation on recognized problem areas, periodic joint program planning, product retention and recalls, and training.

The FDA is responsible under the Food, Drug and Cosmetic Act to insure that foods are safe and wholesome and the products are honestly labeled.

The National Marine Fisheries Service is authorized by the Agricultural Marketing Act and the Fish and Wildlife Act to develop and implement quality grade standards for fishery products and to improve health and sanitation standards in the industry. NMFS also has the authority to conduct both plant and product inspection for fishery processors; through a voluntary inspection program available to the industry.

This agreement will benefit both consumers and industry by extending fishery products in inspection activities to more products and facilities.

In the Memorandum of Understanding between the two agencies, FDA recognizes NMFS' expertise in the field of fishery products quality and sanitary processing. FDA also recognizes that plants under contract of NMFS' voluntary inspection program are subject to inspections which insure compliance with the Federal Food, Drug and Cosmetic Act.

NOAA COASTAL ZONE ROLE IS EXPANDED

Robert W. Knecht

A new post reflecting NOAA's increased involvement in the orderly management of the coastal environment has been created by Dr. Robert M. White, NOAA Administrator.

Robert W. Knecht, Director of the Office of Coastal Zone Management, will serve in the new position of Assistant Administrator for Coastal Zone Management.

In announcing the appointment, Dr. White said: "The elevation of the coastal zone management program to the Assistant Administrator level reflects the fact that the program has come of age. There is a greatly increasing awareness of the need for protecting and making more rational use of the coastal resources of the nation, as well as in developing methods for managing those resources.

"The recent emergence of a wide range of energy problems has focused attention on the coastal zone for deepwater ports, floating nuclear power plants, and offshore oil and gas drilling and has served to draw attention to the program and to the urgent need for closer cooperation between state and federal governments."

OCZM is charged with coordinating with states in their development of a program for managing the coastal zone. In addition to providing grants for program development and implementation under terms of the Coastal Zone Management Act of 1972, it gives technical assistance to states, and is helping them prepare for increased pressures to develop the shore, conflicting uses of the coastal zone, as well as for the on shore impact of oil and gas exploration and related issues. OCZM also has attempted to assure that state concerns are reflected in plans of Federal agencies involved in activities along the coasts.

Mr. Knecht was previously Deputy Director of the Environmental Research Laboratories in Boulder, Colo. He first joined the Government in 1948 with the National Bureau of Standards. In 1967, he was awarded a Department of Commerce Gold Medal for leadership in a satellite experiment.

Sea Slick Is Probed As A Life Saver

A harmless manmade sea slick that is being studied as a hurricane suppressor may also help save lives another way, according to an oceanographer with the Environmental Research Laboratories' Atlantic Oceanographic and Meteorological Laboratories. Duncan Ross, of AOML's Sea-Air Interaction Laboratory in Miami, Fla., believes that a slick-forming chemical, added to the dye packets of life jackets and rafts would make it easier for rescuers to spot shipwreck victims or others cast adrift at sea.

Certain chemicals form temporary sea slicks on the surface of the ocean, covering the water with a thin, polymer membrane only a few molecules thick. A small amount of one such compound—polyvinyl alcohol, lineoleic acid and derivatives of polyvinyl acetate—can produce an acre of slick in 20 minutes, with a clearly visible, stable boundary. The chemicals used have been found to be of low toxicity, and the amounts involved are too small to harm aquatic life.

The manmade slicks, which produce a smoother-looking patch of water, even suppress the ripples on the bow wave of a ship.

This wave-suppressing property, says Mr. Ross, makes polymer sea slicks potential lifesavers. Many life jackets and rafts carry dye packets used in an emergency to create a splotch of bright orange in the water—which, however, is soon dissipated by waves.

The ability of sea slicks to calm the seas, Mr. Ross says, would assist in prolonging the life of the dye patch. Since two ounces of oleal alcohol will form a slick about 200 feet (60 meters) in diameter that last several hours, he suggests adding such a substance to life jacket dye packets.

The slick, he points out, is highly visible and can be detected by airborne radar, so an all weather search could be conducted from high altitudes.

noaa/people

X. William Proenza has been named Executive Assistant to the Director of the National Weather Service Central Region in Kansas City, Mo.

Capt. Lavon L. Posey has been named Special Assistant for Programs and Requirements in the National Ocean Survey's Office of Marine Surveys and Maps.

Eugene R. Hoppe has been named Chief of the Environmental Data Service's new Satellite Data Branch.

Dr. Clarence P. Idyll has been appointed Study Director, National Ocean Policy Study, in the Plans and Program Coordination Office of the Office of Marine Resources. Since 1971 he has been Senior Fishery Management Consultant of the Food and Agriculture Organization in Rome.

George A. Maul, an Oceanographer with the Environmental Research Laboratories' Atlantic Oceanographic and Meteorological Laboratories in Miami, Fla., has been honored recently by the National Aeronautics and Space Administration for his contributions to the Skylab missions, conducted between May 1973 and January 1974.

Ronald S. Hamilton has been appointed Meteorologist in Charge of the Riverside, Calif., National Weather Service Office for Agriculture, where he has been principal Assistant since 1971.

Cdr. Charles K. Townsend has been appointed Commanding Officer to the NOAA Ship Rainier.

Richard C. Raulerson has been named Chief of the Marketing Services Division of the National Marine Fisheries Service Southeast Region, where he has been serving as a marketing specialist.

Edgar F. Law has been named Director of the Special Projects Division of the Environmental Data Service's National Oceanographic Data Center.

John T. Sun has been appointed by the Office of Coastal Zone Management as regional coordinator for Northeastern States.

Dr. Robert A. Clark, Associate Director of the National Weather Service for Hydrology, has been named by Dr. Robert M. White, NOAA Administrator, to the advisory U.S. National Committee for the International Hydrological Program (IHP).

Lt. Cdr. James M. Wintermyre has succeeded Cdr. James P. Brown, Jr., as Chief of the Marine Requirements Coordination Group in the NOS Office of Marine Surveys and Maps in Rockville, Md.

James E. Sykes, who has been Director of the Division of Fisheries at the National Marine Fisheries Service Atlantic Estuarine Fisheries Center in Beaufort, N.C., since 1971, has been elected President of the American Institute of Fishery Research Biologists for a two-year term.

Ansel N. Page, Jr., who has been Chief of the Systems and Applications Division in NOAA's office of Management and Computer Systems since 1973, has been named Chief of Systems Integration and Planning in the Environmental Data Service.

Dr. Robert B. Abel, Director of the Office of Sea Grant, and Edward M. MacCutcheon, retired Director of NOS Systems Development, will be featured speakers at the first annual Ocean Science and Engineering Course to be given next July by UCLA Extension's program of Continuing Education in Engineering/Mathematics/Biological and Physical Sciences.

Edgar A. Hubin of the Environmental Research Laboratories has been appointed Personnel Officer for the combined National Bureau of Standards, Institute for Telecommunication Sciences, and NOAA elements in the Boulder, Colo., area.

Elroy C. Jagler has been appointed Meteorologist in Charge of the National Weather Service Forecast Office (for Wisconsin) at Milwaukee.

Jack Brett is the new Administrative Officer for the National Ocean Survey's Lake Survey Center.

Myra R. Wells, Chief of the National Marine Fisheries Service, Environmental Data Service, National Environmental Satellite Service Personnel Section of NOAA Personnel Division, recently was appointed to represent NMFS as a United State member of the International Fisheries Commissions Pension Society.

Professor Richard W. Rozett, S. J., is on a year's sabbatical to head the effort in the MESA (Marine Ecosystems Analysis) New York Bight project of the Research Division in the Environmental Data Service's Center for Experiment Design and Data Analysis.

M. Karl Jugel, Operations Research Analyst in NOAA's Office of Marine Resources in Rockville, Md., was named the Outstanding Young Man of 1974 by the Bowie Md., Jaycees.

Jim A. Helms, a Weather Service Specialist at Meridian, Miss., has been selected as Official in Charge of the National Weather Service Office at Columbus, Ga. He replaces Thomas J. Floyd, who has retired.

Bruce B. Remsbery has joined the National Ocean Survey's National Oceanographic Instrumentation Center as Chief of its Intercalibration Branch in the Metrology Division.

Keith D. Brouillard has been selected to be the new Regional Fisheries Attache in Tokyo, Japan.

Thomas M. Crawford has been named Library Automation Project Manager in the Environmental Data Service's Environmental Science Information Center.

James F. Lander, Deputy Director of the Environmental Data Service's National Geophysical and Solar-Terrestrial Data Center in Boulder, Colo., has been appointed a Liaison Representative with the Earthquake Engineering Research Institute.

Donald J. Close, who has been Principal Assistant at the National Weather Service River Forecast Center in Harrisburg, Pa., since 1971, has been selected as the NWS Eastern Region Assistant Regional Hydrologist.

Cdr. Richard E. Alderman has been appointed Commanding Officer of the NOAA Ship Fairweather. He was assigned previously to the NOAA Office of International Affairs.

Dr. Steven F. Clifford and **Gerard R. Ochs,** Physicists at the Environmental Research Laboratories' Wave Propagation Laboratory in Boulder, Colo., have been elected Fellows of the Optical Society of America.

John A. Mayer has been named Executive Officer and User Services Representative at NWS Eastern Region Headquarters. He succeeds Gerald L. Shak, who has taken a World Meteorological Organization assignment in Nepal.

Harold M. Gibson is in charge of the New York City Weather Service Forecast Office, which has been relocated from the Bronz Community College Campus to 30 Rockefeller Plaza.

Capt. John O. Boyer has been appointed commanding officer of the NOAA ship Researcher, which is based at Miami, Fla.

Dr. Harris B. Stewart, Jr., Director of the Environmental Research Laboratories' Atlantic Oceanographic and Meteorological Laboratories in Miami, Fla., has been elected vice-president of the International Oceanographic Foundation.

Cdr. Ray E. Moses is the new manager of the National Ocean Survey's Marine Data Systems Project, which is engaged in a ten-year $25 million program to develop automated nautical charts.

Albert R. Hinn, who has been Meteorologist in Charge of the National Weather Service Office in Richmond, Va., for the past year and a half, has been named MIC at the Wilmington, N.C., WSO.

Lt. Cdr. Paul M. Duernberger has moved up from Navigation Officer to Operations Officer of the Miami-based NOAA Ship Researcher.

Sidney O. Marcus, Jr., of the Environmental Data Service's National Oceanographic Data Center, has replaced Dr. Woodrow C. Jacobs (former Director of EDS) as the editor of the English translation of the Russian journal Okeanologiia.

Ray R. Waldman, Meteorologist in Charge at the National Weather Service Forecast Office in Chicago, Ill., has been awarded a Distinguished Service Citation by the Defense Civil Preparedness Agency.

Lt. Cdr. Floyd Childress, II, is the new Executive Officer of the NOAA Ship Ferrel.

Dr. Murray Dryer, a physicist with the Environmental Research Laboratories' Space Environment Laboratory in Boulder, Colo., since 1965, has been given the Space Science Award for 1975 by the American Institute of Aeronautics and Astronautics.

Jack J. Schnabel, who has been in charge of the Abilene, Tex., Weather Service Office since 1972, has been selected to head the Jacksonville, Fla., WSO.

Lt. Cdr. John K. Callahan, Jr., has joined the staff of the Director of the National Ocean Survey in Rockville, Md., after more than two years at sea as Executive Officer of the NOAA Ship Peirce.

Cdr. Charles A. Burroughs is the new Chief of the Operations Division at the National Ocean Survey's Pacific Marine Center in Seattle, Wash.

Dr. Eldon V. Jetton, who has served as head of the National Weather Service Forecast Office in Little Rock, Ark., since 1971, has been selected as Meteorologist in Charge of the WSFO at New Orleans, La. He succeeds W.C. Conner, who has retired.

Cdr. Darrell W. Crawford has been appointed Director of the National Ocean Survey's Lake Survey Center in Detroit, Mich. He succeeds Capt. Kenneth A. MacDonald.

Cdr. William R. Curtis is now Executive Officer of the Seattle-based NOAA Ship Oceanographer.

GFDL MODEL SIMULATES ATMOSPHERE

Three Environmental Research Laboratories scientists have developed a mathematical model of atmospheric circulation that will enable them to experiment with weather and climate without leaving the laboratory.

Dr. Syukuro Manabe, Douglas G. Hahn and J. Leith Holloway, Jr., of the Geophysical Fluid Dynamics Laboratory in Princeton, N.J., recently tested the model by comparing its simulation of seasonal variations in the tropical circulation with observations made in the "real" tropics. They concluded that the model does a good job of describing the major features of the tropical circulation, and provides new insights into the causes and patterns of tropical climate.

With an accurate, realistic model, says Dr. Manabe, atmospheric scientists can manipulate different variables to see how they influence weather and climate. For example, the model was used to find out if a change in the surface temperature of the Arabian Sea would affect the Indian monsoons. Much of the warm water vapor that drives the monsoon comes from the Arabian Sea. Experiments with the NOAA circulation model suggest that cooling the sea would decrease the intensity of the monsoons. Other experiments, says Dr. Manabe, might apply to the causes of drought in Africa.

The researcher observed weather in the tropics of their model, simulated with high speed computers. The model takes into account such factors as seasonal changes in the amounts of solar radiation reaching the earth's surface, sea surface temperatures, and the distribution of mountain ranges, all of which influence circulation and weather.

The earth is girdled in the tropics by a belt of heavy rainfall, the tropical rainbelt. Over the continents, the rainbelt moves through different latitudes with the seasons, sometimes straddling the equator. Although some researchers have suggested that the rainbelt avoids the equator over the continents, the rainbelt in the NOAA model displays no such tendency.

The researchers note that the model has some flaws but on the whole, they conclude it makes a realistic imitation of tropical circulation, and should be a powerful tool for experiments with weather and climate.

PRESIDENT NAMES NINE TO NACOA

President Ford has announced the appointment of nine persons as members of the National Advisory Committee on Oceans and Atmosphere. They are:

Thomas Lloyd Kimball of McLean, Va., Executive Director of the National Wildlife Federation, who was appointed for the remainder of a term expiring Oct. 18, 1976. He succeeds Dr. Thomas Clingan, who resigned.

Dr. Donald Lynn McKernan, of Redmond, Wash., Professsor in the Institute of Marine Studies at the University of Washington in Seattle. He succeeds Dr. Charles L. Drake, whose term expired. The President also designated Dr. McKernan as Vice Chairman of the Committee.

Dr. William J. Hargis, Jr., of Gloucester Point, Va., Director of the Virginia Institute of Marine Science in Gloucester Point, who was reappointed. Dr. Hargis also was designated by the President as Chairman of the Committee.

Charles A. Black of Woodside, Calif., President of the Mardela Corporation of Burlingame, Calif. He succeeds Thomas A. Fulham, whose term expired.

Marne Arthur Dubs of New Canaan, Conn., Director of Ocean Resources, Kennecott Copper Corporation of New York. He succeeds Charles F. Baird, whose term expired.

Dr. Helmut E. Landsberg, of Camp Springs, Md., Professor in the Institute for Fluid Dynamics at the University of Maryland. He succeeds Brig. Gen. Joseph J. George, USAF retired, whose term expired.

Dr. Grover E. Murray, of Lubbock, Tex., President of Texas Tech University in Lubbock. He succeeds Dr. Wayne Burt, whose term expired.

Dr. William E. Nierenberg, of La Jolla, Calif., Director of Scripps Institution of Oceanography in La Jolla, who was reappointed.

Dr. John Wilder Tukey of Princeton, N. J., Professor in the Department of Mathematics at Princeton University in Princeton. He succeeds Dr. Thomas F. Malone, whose term expired.

Established by Public Law 92-125 of August 16, 1971, NACOA conducts a continuing review of the progress of the Nation's marine and atmospheric science and service programs, and advises the Secretary of Commerce with respect to NOAA. It submits a comprehensive report to the President and the Congress by June 30 each year setting forth an overall assessment of the status of the Nation's marine and atmospheric activity.

Tomorrow's Farmer: He May Grow Lobster

That cantankerous delicacy, the American lobster, is on his way to being "domesticated" for aquaculture purposes by a Sea Grant research team at the University of California's Bodega Marine Laboratory.

The interdisciplinary group headed by Dr. Robert A. Shleser is working to develop a commercially feasible system to farm lobsters and other marine animals. Within recent months they have reported success in:

—Obtaining 80 percent survival of lobsters through the larval period;

—Reducing cannibalism, a recurring and significant problem in lobster aquaculture;

—Developing a more cost-effective feed;

—Achieving successful matings, egg extrusion, and hatching.

Using the sophisticated tools of genetics, biochemistry, and systems engineering, the Sea Grant team devised a larval rearing system that now achieves up to 80 percent survival of lobsters through the larval period.

The goal of the project is to develop the technology required so that lobsters can be grown to marketable size and harvested profitably.

Student Kim Novotny of Kitsap County, Wash., vaccinates a coho salmon in NMFS program at Northwest Fisheries Research Center. NMFS is developing vaccines against salt-water salmon's greatest killer, the vibrio *bacterium.*

NOAA Marine Advisory Unit, Ag Extension, Sign Pact

Close working relationships between State Cooperative Extension Services and NOAA's marine advisory programs will be provided under a recent landmark agreement.

Under the pact, the Extension Service of the U.S. Department of Agriculture representing State Cooperative Extension Services and NOAA will work together to provide extension-type services to the marine community.

NOAA will prepare a plan for developing marine extension and advisory programs in coastal and other interested states, and advise Extension Services of programs that might pertain to cooperative extension. Upon concurrence by the Extension Service, the two services will coordinate the design of educational programs for disseminating information generated by NOAA and will develop and support education programs on national, regional, state and local levels.

NOAA's Marine Advisory Service will also cooperate with the Extension Service in preparing educational materials and will provide funding where appropriate.

In addition, the Extension Service will coordinate with NOAA in developing and conducting training programs through State Cooperative Extension Services, provide information to NOAA on marine resources and environmental problems concerning agricultural and rural communities, and assist in negotiating contracts and agreements between the State Cooperative Extension Services and NOAA.

NOAA's Marine Advisory Service is under the direction of Howard Eckles, and operates under the aegis of the National Sea Grant Program. It involves advisory activities of other NOAA components as well as those of Sea Grant.

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Skywarn '75 Under Way; '74 Severe

The year 1974 produced the most devastating outbreak of tornadoes ever recorded anywhere in the world, according to National Weather Service meteorologists, who have launched their annual SKYWARN campaign.

"If ever there was a year underscoring the value of advance preparedness against tornadoes, last year was it," said NWS Director Dr. George P. Cressman. He said the outbreak of 148 tornadoes in 13 states on April 3 and 4 was unprecedented in number, combined strength, and total path length. "The toll of about 300 dead was agonizingly high," he said, "but not the highest on record. That was set on March 18, 1925, when a single tornado ripped through parts of Missouri, Illinois and Indiana, killing 689 people. I'm sure many lives were saved last April because of improvements in our knowledge of how best to cope with these killer storms."

Each year the NWS launches SKYWARN before the peak of the tornado season to encourage community leaders to prepare for the violent funnel-shaped whirlwinds. Among recommendations are to fill out ranks of volunteer storm spotters, improve communications systems and remind citizenry of ways to shield themselves from a tornado's explosive effect.

"Because tornadoes are so sudden in onset, it is essential to have a well-rehearsed plan for quick action when a tornado is reported bearing down," said Dr. Cressman. "There is no question that such plans save lives."

The alerting system has two phases: a *tornado watch*, which tells that atmospheric condictions are ripe for tornadoes to form, and a *tornado warning*, which tells that a tornado actually has been spotted or indicated by radar.

Most sightings of the ominous, funnel-shaped clouds are made by volunteer spotters who pass the word to official warning centers.

The Weather Service urges officials in schools, hospitals, factories, and large apartment complexes to develop special preparedness plans. A booklet telling how to set up an effective program is available to community and other leaders from the NWS Community Preparedness Office, in Silver Spring, Md.

944 TORNADOES IN 1974 - 2ND HIGHEST ON RECORD*
(Upper figures are numbers of tornadoes. In parentheses, tornado deaths)
Tornadoes
Hawaii——1 (no deaths)
Alaska——0
Puerto Rico——1 (no deaths)
UNITED STATES AS A WHOLE
944 TORNADOES†
(361) TORNADO DEATHS

* All-time high for tornadoes was 1,108, set in 1973. All-time high for tornado deaths, 794, was set in 1925 (figures for 1974 may change slightly when the final tally is made).

† State-by-state totals add to 955 tornadoes, because 11 tornadoes crossed state borders.

Flemming Award Goes To GATE's Sargeant

Dr. Douglas H. Sargeant, Director of the World Weather Program Office received the Arthur S. Flemming Award February 27 in Washington. The awards are made annually by the D.C. Junior Chamber of Commerce to honor ten of the Nation's most outstanding young government employees.

Dr. Sargeant was cited for his work in 1974 as Director of the U.S. Project Office of GATE—the Atlantic Tropical Experiment of the Global Atmospheric Research Program, the largest and most complex international scientific experiment ever undertaken. The field phase of GATE completed last fall in the Atlantic off Senegal in Africa, involved approximately 5,000 persons from 70 nations, and a wide array of satellites, aircraft, ships and other scientific platforms.

According to the citation, "Dr. Sargeant's resourceful management helped overcome a threatened loss of vital satellite information and other equipment difficulties. His skill in complex international negotiations helped during operating agreements acceptable to all nations involved. His outstanding scientific and executive ability combined with his diplomacy in relations with other nations and his agressive pursuit of his leading role in this mission, brought about a truly international scientific and operational plan."

Survey Completes SCOPE In Record Time

The National Ocean Survey has completed in two years a survey of a 38,000-square-nautical-mile area of coastal waters off the Carolinas, Georgia, and northern Florida which previously had been programmed for completion in 1988.

Dubbed SCOPE (Southern Coastal Plains Expedition), the survey will provide marine information on the coastal plain region to aid Federal, state, local and private agencies in making decisions on environmental problems. It also will serve as a prototype for similar concentrated surveys in other major coastal areas as funds and facilities become available.

Processing of the date has been speeded up in order to expedite the release of information for environmental development studies, such as ecology, pollution control and marine engineering, and for nautical charts.

In compressing the 15-year-survey into two years, the NOS used the NOAA ships Whiting, Mt. Mitchell, Peirce and Ferrel, a hydrographic field party, land support units, and an air photo mission. The ships and hydrographic party covered approximately 76,000 miles, equivalent to more than three times around the globe, in carrying out their surveys from Cape Hatteras, N.C., to the vicinity of Cape Canaveral, Fla., and out to sea as much as 60 miles.

Sea Grant Seeks To Improve Diving Safety

Concerned about the growing rate of fatal diving accidents in the United States as the sport of recreational diving burgeons, NOAA, the State of California, and a private citizen have initiated a project at the University of California, and a private citizen have initiated a project at the University of California at Los Angeles to improve diving safety.

Dr. Glen Egstrom of UCLA's Department of Kinesiology, who is also President of the National Association of Underwater Instructors and a member of the Los Angeles County Underwater Safety Committee, directs the project for which NOAA's Sea Grant program provided $30,200.

Learning of the NOAA search for an experienced, qualified organization that could undertake the work quickly, Leonard Greenstone of Los Angeles, a recreational diver and scuba instructor who has been concerned about the carelessness and lack of knowledge exhibited by many sports divers, called Sea Grant's attention to the capabilities of Dr. Egstrom's UCLA team, and followed up with a $15,000 commitment. UCLA has obtained $15,745 in matching funds to support the project.

UCLA has for several years been a center for the study of man's performance underwater, examining human effectiveness under a variety of environmental conditions, with different kinds of equipment and for varying types of jobs.

Potomac River NOS Survey

The most comprehensive nautical charting survey ever made of the Potomac River from Washington to the point where the river enters Chesapeake Bay 97 miles away has been completed.

Two National Ocean Survey hydrographic parties completed surveying the last segments of the river in a program which began in 1959. The hydrographic data are being used to modernize the NOS nautical charts of the river and in support of environmental studies of the waterway.

The first official surveys of the Potomac River basin were along the Washington waterfront and date back to 1837. Geodetic control surveying along the lower Potomac was conducted in 1849, but it was not until 1859 that complete surveys for charting the river from its entrance to the head of tidewaters were fully underway.

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Aero Charts To Add Major Power Lines

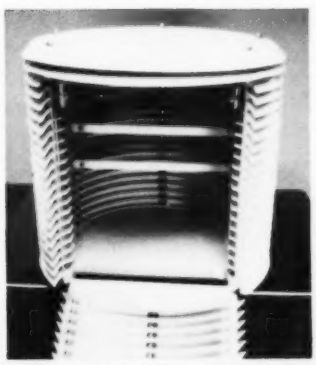
NOAA has announced plans to include on its aeronautical charts, as a new safety measure, all major systems of power transmission lines.

This step is in line with a recommendation of the Interagency Air Cartographic Committee, composed of representatives of the Department of Commerce, the Department of Defense, and the Federal Aviation Administration. According to the National Transportation Safety Board, there were 147 aircraft accidents in 1971 involving wires and poles, 31 of them fatal.

Large steel transmission towers and their connecting power lines are often a hazard to low level flying, but they also provide good visual landmarks for aircraft, especially when they pass through dense vegetation, including forests, where lanes have been cleared.

Stephen Yachmetz, Jr., is Chief of the National Ocean Survey's Aeronautical Chart Division, which prepares and issues about 49 million aeronautical charts each year. The charts now carry some power lines, based on flight surveys conducted by NOAA aircraft, but most power lines are not presently on the charts.

The NOS has asked 113 power companies in 43 states and the District of Columbia for information concerning the nature and location of their distribution systems, pointing out that location and alignment of transmission lines, in particular their relationship to railroads, highways, rivers and other cultural features, are of utmost importance to guarantee the accuracy of the charts.



NWS is testing new plastic instrument shelter at Sterling, Va., Research and Development Center.

WEATHERMOD PLAN REVAMPED

NOAA's weather modification research facilities in Miami, Fla., have been reorganized. The changes, developed by the Environmental Research Laboratories's Weather Modification Program Office in Boulder, Colo., reflect increasing interaction between researchers in tropical meteorology and the requirements of NOAA's new aircraft and instrumentation systems, scheduled to enter service in 1976.

The reorganization combined the National Hurricane Research Laboratory, and the Experimental Meteorology Laboratory.

Within the new laboratory, four groups—hurricane, cumulus, analytical studies, and modeling—will provide the scientific teams needed to conduct the unit's research in tropical meteorology and weather modification. The facility will remain at the Coral Gables campus of the University of Miami.

ERL's Research Flight Facility, based at Miami International Airport, will be reorganized to separate flight operations and scientific instrumentation, and renamed the Research Facilities Center.

Merlin C. Williams is Acting Program Manager for Weather Modification in Boulder.

"In combining the laboratories at Coral Gables," he explains, "we are simply recognizing that cumulus clouds and hurricanes occupy different ends of the tropical meteorology scale. A team approach within a single laboratory can bring additional talent and experience to bear anywhere along that scale.

"And we will be going more to the aircraft manager concept on the new airplanes. This technique, which puts an aircraft manager between the aircraft commander and the mission scientists, works very well for NASA and should be effective aboard the P-3's."

Two other elements of the Weather Modification Program Office—the Instrumentation Task Force, and the Boundary Layer Dynamics Group, both based in Boulder—are not affected by the present reorganization.

Fishermen Found By NWS Boat

National Weather Service personnel on Islas Del Cisne (Swan Island), Honduras, risked their lives recently to save some 19 lobster fishermen forced to abandon their sinking ship.

When the Lucky Girl began to sink about 20 miles NNW of Swan Island, late one night in December, Captain Corwin Forbes ordered his 21 men into the ship's dugouts. Then he sent out an SOS, and abandoned the vessel at 11:45 p.m.

The SOS was picked up by a fishing vessel 180 miles away and finally relayed to Islas Del Cisne at 7:45 a.m. the next day, just as the first canoe landed and its three occupants staggered ashore with details of the sinking.

The "Swan Island Navy" immediately went into action to try to locate the other fishermen. Despite rough seas, Spencer Bennett and Simmons Tatum went northwest in the NWS motorboat to search. Ronnie More and Cardy Bennett, in Moore's motorboat, went southwest. They found three canoes with nine survivors, and towed them to the island.

Official-in-Charge Walter H. Glassman, instructed Hal Hoots to contact the U.S. Coast Guard in Miami by teletype for assistance at the request of the vessel's owner. However, because of technicalities, the Coast Guard's planned search by plane did not materialize.

The NWS motorboat returned to be refueled and subsequently found the other five canoes and the remaining ten survivors about eight miles southwest of the island, and towed them to safety.

AMS' Abbe Award To Dr. Cressman

Several NOAA personnel and former personnel were honored by the American Meteorological Society at its recent 55th Annual Meeting in Denver, Colo.

Dr. George P. Cressman, Director of the National Weather Service, received the Society's 1975 Cleveland Abbe Award for Distinguished Service to Atmospheric Sciences by an individual, for "pioneering efforts in introducing numerical techniques into weather forecasting and his outstanding leadership in modernizing the United States Weather Service.

Dr. William H. Klein, Director of the NWS Techniques Development Laboratory and Acting Director of the Systems Development Office, received the AMS Award for the Outstanding Contribution to the Advance of Applied Meteorology for "his notable development of objective procedures for predicting surface weather elements and his leadership in bringing these and other scientific advances in meteorology into practical use."

Dr. Werner A. Baum, who was Deputy Administrator of the Environmental Science Services Administration, NOAA's predecessor, in 1967 and 1968, was awarded the AMS 1975 Charles Franklin Brooks Award for Outstanding Services to the Society. Dr. Baum, who is now Chancellor of the University and Professor of Geography at the University of Wisconsin at Milwaukee, was cited for "his numerous exemplary services to the Society and the profession, and his leadership as an educator."

Dr. Neil L. Frank, Director of the NWS National Hurricane Center in Miami, Fla., and Dr. Joanne Simpson, former Director of the Environmental Research Laboratories' Experimental Meteorology Laboratory in Miami, who is now Professor of Environmental Sciences at the University of Virginia in Charlottesville, Va., were among the four AMS members elected by the Society to serve three-year terms as Councilors.

The National Weather Service Office at Huntsville, Ala., received one of three 1975 AMS Special Awards presented to individuals or organizations not recognized by more specifically defined awards, who have made important contributions to the science or practice of meteorology or to the Society. WSO Huntsville was cited for its "timely and accurate warnings during the tornadic outbreak of April 3, 1974, is disregard of personal safety, maintaining information services that helped to minimize the impact of a series of vicious storms."

Oil Firms Give EDS Storm Data

Shell Oil Company, Houston, Tex., acting on behalf of eight petroleum firms has donated to NOAA oceanographic and meteorological data on major storms and hurricanes striking the Gulf of Mexico in 1969, 1970, and 1971.

The data were collected at a cost exceeding one million dollars in a cooperative petroleum industry effort called the Oceanographic Data Gathering Program

Data on wave height, wind speed and direction, and barometric pressure were taken at six offshore drilling and production platforms spaced along 260 miles of the Louisiana coastline. The data comprise 252 analog magnetic tapes covering a 31-month period and are available through the Environmental Data Service.

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On Feb. 11, 1975, at 2:25 pm, the first SMS-2 pictures of cloud elements 2-miles or greater in size were recorded (See page 42).

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